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# NAVIGATION CONDITIONS AT GALLIPOLIS LOCKS AND DAM, OHIO RIVER

**AD-A209 400**

Hydraulic Model Investigation

by

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<p><u>Gallipolis Locks and Dam, located on the Ohio River approximately 279.2 miles below Pittsburgh, PA, is one of the original 46 locks and dams provided for navigation. The capacity of the existing locks and their approaches are inadequate for present and projected traffic. Alternatives considered for the improvement of conditions included the construction of either one 1,200-ft lock, one 1,200-ft lock and a 600-ft lock, or two 1,200-ft locks in a canal bypassing the existing structure, with and without the use of the existing locks with some improvements; and a complete replacement structure with two 1,200-ft locks about 3 miles downstream. Two fixed-bed models constructed to scales of 1:120 were used to study navigation conditions at the existing site and at the replacement site. The model studies indicated that conditions at the existing site would continue to be difficult and hazardous for downbound tows using the existing locks although some</u></p>				
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improvements could be made. Satisfactory navigation conditions could be developed with one or two locks in the bypass canal at the existing site, and provisions could be made for two-way traffic under most conditions with two locks in the bypass canal. Navigation conditions for downbound tows approaching the locks with the replacement structure (alternate site) would tend to be difficult and hazardous with the plan as originally proposed, because of the alignment of the right bank upstream and the alignment and high velocity of currents approaching the locks. A satisfactory plan was developed by shifting the structures downstream, rearranging the lock auxiliary walls, and modifying the excavation of the adjacent (right) bank.

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PREFACE

The model investigations described herein were authorized by the Office, Chief of Engineers (OCE), on 25 May 1970 at the request of the US Army Engineer District, Huntington. The study was conducted in the Hydraulics Laboratory of the US Army Engineer Waterways Experiment Station (WES), Vicksburg, MS, during the period June 1970 to November 1978 and January 1980 to December 1985. The study was suspended during the period July 1972 to September 1977 and December 1978 to December 1979.

During the course of the model study, representatives of the US Army Engineer Division, Ohio River; Huntington District; and other navigation interests visited WES at different times to observe special model tests and to discuss test results. The Huntington District was kept informed of the progress of the study through monthly progress reports and reports at the end of each test.

The model study was conducted and this report prepared under the general supervision of Messrs. E. P. Fortson, Jr., and H. B. Simmons, former Chiefs of the Hydraulics Laboratory, F. A. Herrmann, Jr., present Chief of the Hydraulics Laboratory, and R. A. Sager, Assistant Chief; and under the direct supervision of Messrs. J. J. Franco and J. E. Glover, former Chiefs of the Waterways Division, Mr. M. B. Boyd, present Chief of the Waterways Division, Mr. T. P. Pokrefke, Assistant Chief of the Waterways Division, and Ms. C. M. Holmes, Chief of the Navigation Branch. The engineer in immediate charge of the model study was Mr. L. J. Shows, former Chief of the Navigation Branch, assisted by Mr. R. T. Wooley, Navigation Branch. This report was written by Messrs. Shows and Wooley and edited by Mrs. M. C. Gay, Information Technology Laboratory, WES.

COL Dwayne G. Lee, EN, is the Commander and Director of WES.  
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## CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

<u>Multiply</u>	<u>By</u>	<u>To Obtain</u>
cubic feet	0.02831685	cubic metres
degrees (angle)	0.01745329	radians
feet	0.3048	metres
miles (US statute)	1.609344	kilometres

NAVIGATION CONDITIONS AT GALLIPOLIS LOCKS AND DAM

OHIO RIVER

Hydraulic Model Investigation

PART I: INTRODUCTION

Location and Description of Prototype

1. Gallipolis Locks and Dam is located approximately 279.2 miles\* below Pittsburgh, PA, and about 9 miles below the city of Gallipolis, OH (Figure 1). It is one of the original 46 locks and dams with usable main lock dimensions of 110 by 600 ft constructed for the authorized slack-water project for a minimum 9-ft navigable depth along the 981-mile length of the Ohio River and on 7 of its major tributaries. One of the major tributaries, the Kanawha River, flows into the Ohio River at Point Pleasant (mile 265.7), which is in the Gallipolis upper pool area. The pool created by Gallipolis Dam at a normal elevation of 538.0\*\* extends 41.7 miles up the Ohio River to the Racine Dam site and 31.1 miles up the Kanawha River to the Winfield Locks and Dam. The Kanawha River provides waterway access to south-central West Virginia, while the section of the Gallipolis pool extending into the upper Ohio River provides waterway access to Pittsburgh, PA, and beyond. The Gallipolis Locks and Dam is located in one of the most heavily navigated portions of the Ohio River. The Gallipolis pool reach is highly developed with numerous industrial plants. With the increase of barge traffic and barge sizes operating in this area, emphasis is placed on the vital and strategic location of Gallipolis Locks and Dam.

History of Navigation Improvements on the Ohio River

2. In its natural state the Ohio River was obstructed throughout its entire length by snags, rocks, gravel, and sandbars, which rendered navigation

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\* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 4.

\*\* All elevations (el) and contours cited herein are in feet referred to the National Geodetic Vertical Datum (NGVD).

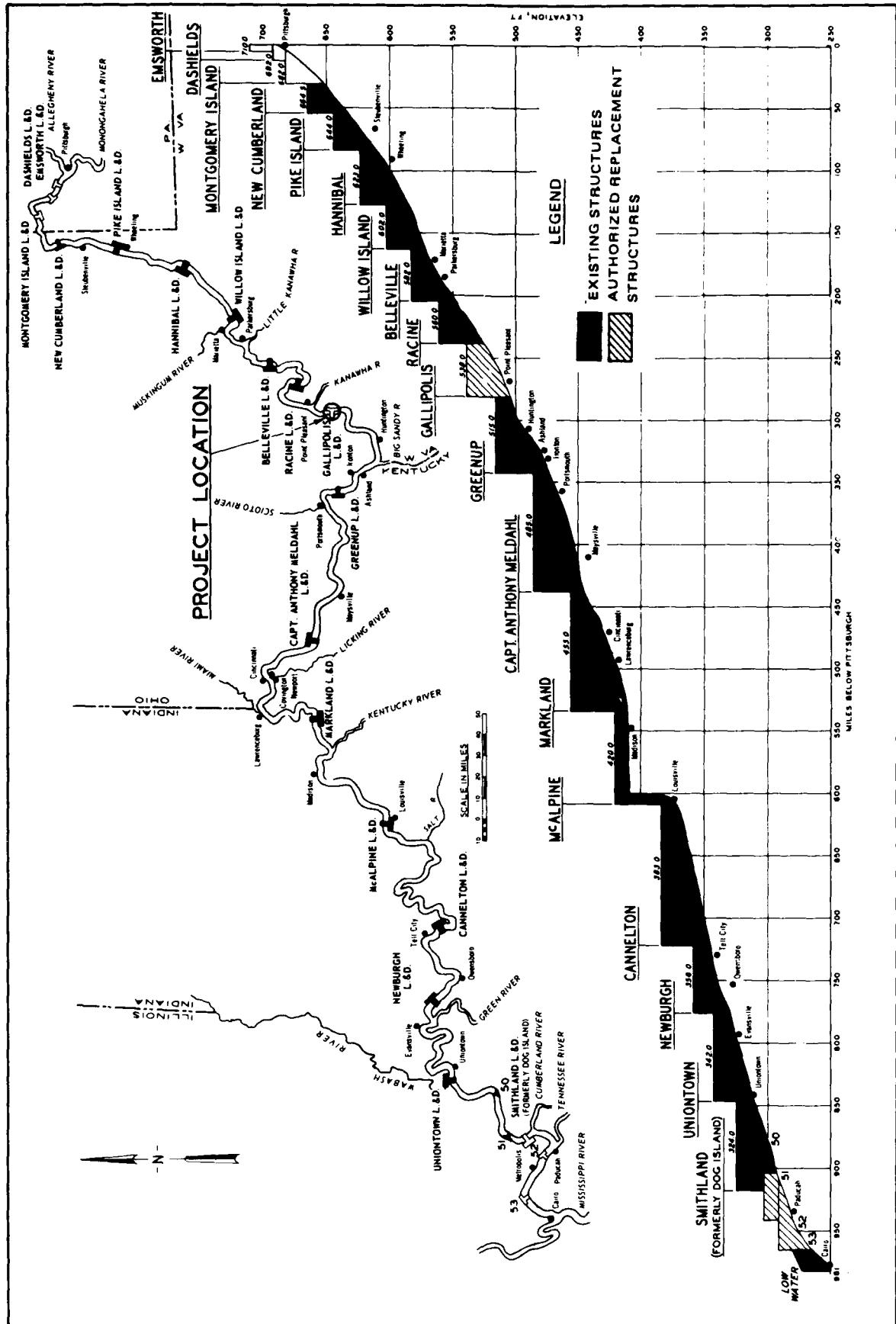


Figure 1. Location map

extremely difficult and hazardous. Controlling depths during low water were 1 to 2 ft from Pittsburgh, PA, to the mouth at Cairo, IL. During the period from about 1824 to 1910, funds were appropriated periodically for navigation improvements, which consisted primarily of removing snags and wreckage from the channel and constructing stone training dikes to contract the channel and increase the scouring action of the river. During this period the principal Ohio River traffic consisted of downbound coal. Large coal tows were assembled in the Pittsburgh harbor area and moved downstream during higher river stages that provided sufficient depth. Little consideration was given to upbound traffic because the amount of upbound traffic was very small.

3. Initially, coal transport interests opposed the construction of locks and dams. They preferred unimpeded navigation under open-river conditions. However, they eventually recognized that adequate low-water depths could not be provided by open-river regulatory works without constricting the channels. This constriction would create excessive velocities that would be hazardous to downbound navigation and would render upstream navigation nearly impossible. To overcome objections to obstacles that would delay downbound traffic, a movable dam was installed that could be lowered to the bed of the river to allow free passage of navigation during periods when natural flows provided sufficient depth.

4. The existing project for the Ohio River was authorized by the River and Harbor Act approved 25 June 1910, 18 July 1918, and 30 August 1935. The project consists of maintained channels and a system of locks and dams that provide a minimum 9-ft navigation depth for the entire length of the Ohio River. Before modernization of the system was undertaken, the lock and dam project consisted of 46 structures, each with a main lock 110 ft wide by 600 ft long. At four of the structures, auxiliary locks 56 ft wide by 360 ft long were provided. Most of the dams were of the movable type and were lowered to the riverbed during flood conditions, thereby allowing navigation to proceed over the pass section of the dam. Navigation channel widths are generally in excess of 500 ft, except at critical bars where 300-ft-wide channels are maintained by periodic dredging.

#### Condition of Existing Gallipolis Structure

5. The Gallipolis Dam, placed in operation in 1937, is a nonnavigable

high-lift structure with eight roller gates having a clear span of 125.5 ft between 16-ft-wide piers. Normal lower pool elevation is 515 and normal upper pool elevation is 538 (23-ft normal lift). The locks consist of a 110- by 600-ft main lock and a 110- by 360-ft auxiliary lock, located along the left bank of the river. Both are single-lift locks.

#### The Problem

6. The capacity of the existing locks at Gallipolis and their approaches are inadequate because the heavy traffic causes long delays and the adverse currents create extremely difficult and hazardous downbound navigation conditions, particularly during the higher flows. In addition, the larger tows have to be disassembled for lockage. Downbound tows approaching the locks during high flows have to maneuver along the left bank cells and use mooring lines to work their way around the bend and into the protection of the upper guard wall. This procedure is very laborious and time-consuming, and traffic is increasing every year.

#### Proposed Improvement Plans

7. As stated previously, the existing locks and dams on the Ohio River were designed primarily to accommodate downbound coal traffic, as upbound traffic was extremely limited at that time. The position of the locks in reference to the currents was not considered overly important at that time because navigation generally ceased during high riverflows. The sizes of the lock chambers were based solely upon the ability of the lock to pass in a single lockage a normal coal fleet of 10 barges and a towboat. Modern tows are much larger and more powerful and operate during most all flow conditions.

8. To provide modern facilities and efficient service for current and anticipated traffic, two alternatives were tested for improving navigation conditions in the Gallipolis area. One alternative scheme consisted of one or two 110-ft-wide by 1,200-ft-long locks or one 110-ft-wide by 1,200-ft-long and one 110-ft-wide by 600-ft-long lock in a cutoff canal along the left bank adjacent to the existing structure. The other alternative consisted of replacing the existing structure with new locks and dam 3.1 miles downstream. The new structure would consist of two parallel locks 110 ft wide and

1,200 ft long and a nonnavigable gate spillway.

#### Need for and Purpose of Model Study

9. The general design of both improvement alternatives was based on sound theoretical design practice and experience with similar type structures on the Ohio River; however, it was desired to ensure that the designs provide the best arrangement and method of operation of the locks and dam for greater efficiency and elimination of any undesirable flow conditions that might make navigation for tows entering or leaving the locks difficult or hazardous. Also to be considered were modifications that would improve conditions at the existing locks and possible use of the existing locks with any new structures. Since navigation conditions vary with location and with flow conditions upstream and downstream of a structure, an analytical study to determine the hydraulic effects that can reasonably be expected to result from a particular design or modification is both difficult and inconclusive. Therefore, comprehensive physical hydraulic models were considered necessary to determine the following:

- a. The best arrangement of the locks and auxiliary lock walls in the bypass canal, size and alignment of the canal, and effect of the canal on navigation conditions at the existing locks.
- b. The effects of lock filling and emptying on navigation conditions in the lock approaches.
- c. Effectiveness of various modifications proposed for the improvement of navigation conditions at the existing locks.
- d. Navigation conditions that would develop with the proposed replacement structure and modifications required to improve efficiency and eliminate any undesirable conditions noted.

The models were also to be used to demonstrate for navigation interests the conditions resulting from the proposed designs, and to assure these interests of the design's acceptability from a navigation standpoint.

## PART II: THE MODELS

### Description

10. The first model used in the study reproduced the reach of the Ohio River between about miles 277.0 and 280.4 and included the existing lock and dam structure and sufficient overbank area to provide for the proposed bypass canal (Figure 2). The second model reproduced the reach of the river between about miles 280.7 and 284.3 based on the location proposed for the replacement lock and dam structure (Figure 3). The models were of the fixed-bed type with the channel and overbank areas molded in sand-cement mortar to sheet metal templates. Portions of the models where changes could be anticipated were molded in pea gravel to facilitate modifications that might be required to incorporate proposed plans or to improve navigation conditions.

11. The first model was constructed with the existing locks and dam structures in place, and provisions were made in the second model to install the locks and dam as initially proposed. The locks, auxiliary lock walls, dams, and piers were constructed of sheet metal. The dam gates were simulated schematically with simple sheet metal slide-type gates that could be raised or lowered as required to maintain the upper pool elevation during control flows. The models were molded to the configurations indicated by hydrographic surveys dated 1963 to 1965 and a topographic survey dated 1959. Overbank areas were extended to a maximum elevation of at least 550 ft at the existing site except for the left overbank, which included the area for the proposed canal. Overbank areas at the replacement site were extended to el 555.

### Scale Relations

12. The models were built to an undistorted linear scale ratio of 1:120, model to prototype, to obtain accurate reproduction of velocities, crosscurrents, and eddies that would affect navigation. Other scale ratios resulting from the linear scale ratio are shown in the following tabulation. Measurements of discharge, water-surface elevations, and current velocities can be transferred quantitatively from model to prototype equivalents by means of these scale relations.

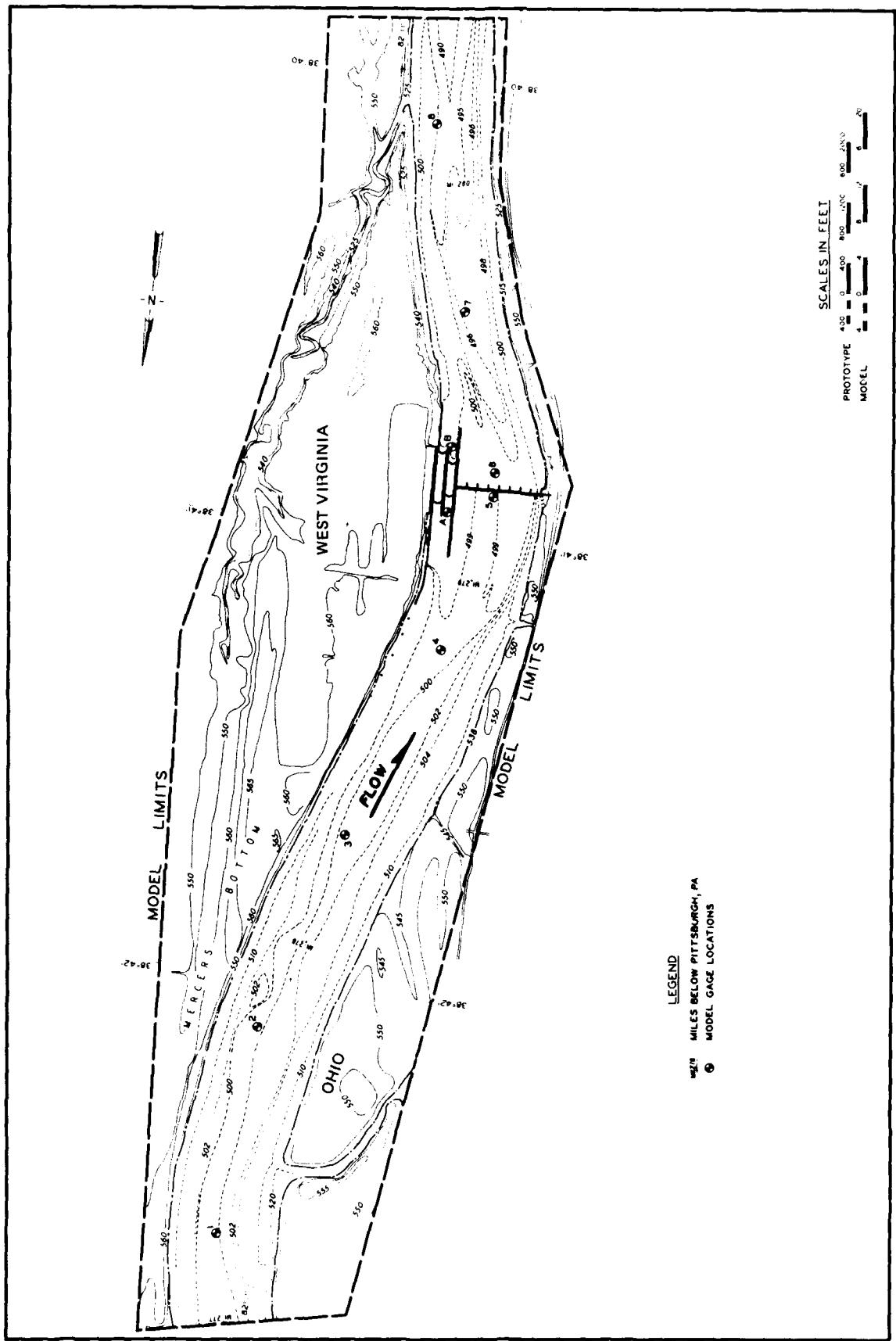


Figure 2. Model layout and location of gages, existing site

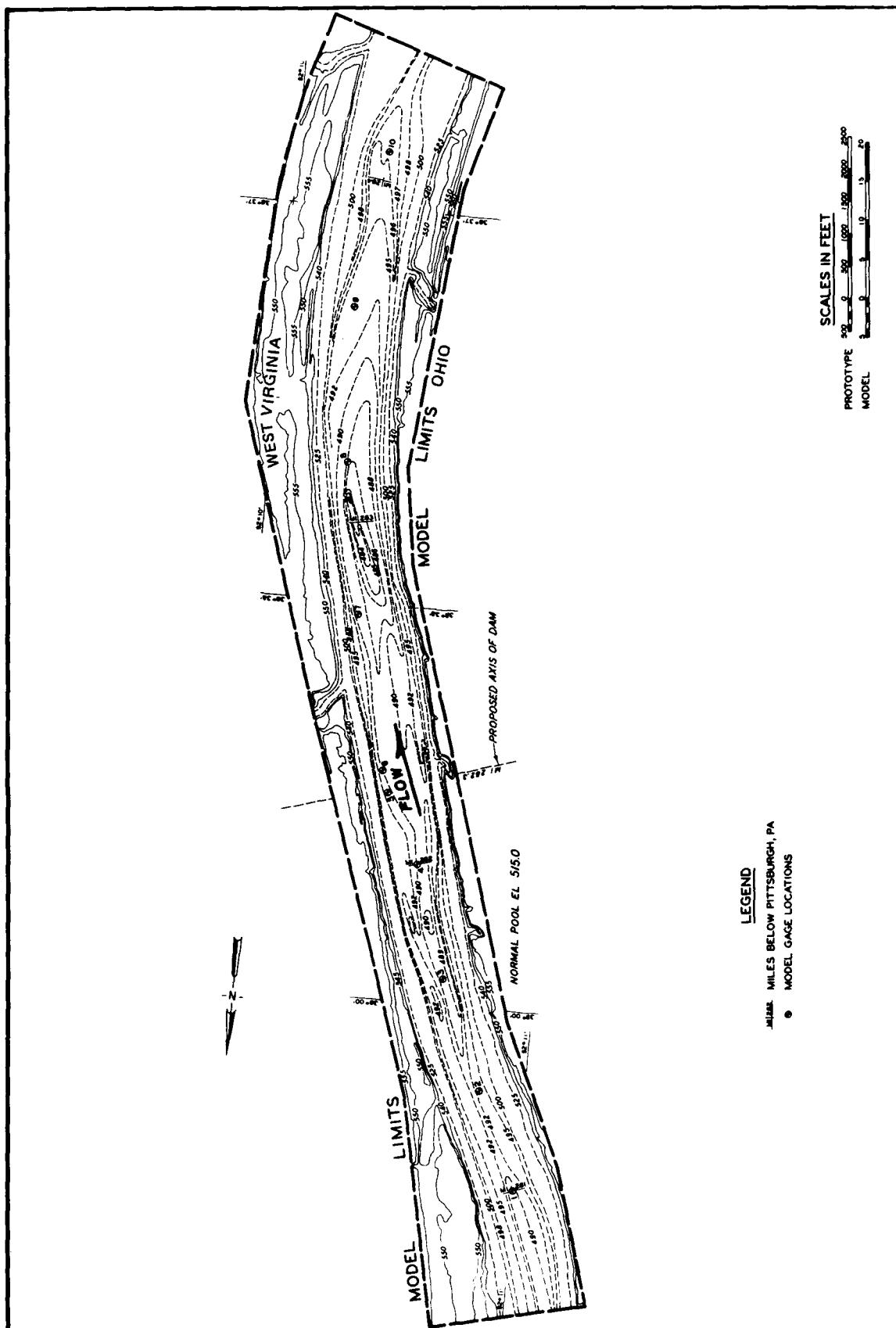


Figure 3. Model layout and location of gages, existing condition at alternate site

<u>Dimension</u>	<u>Scale Relation Model:Prototype</u>
Area	1:14,400
Velocity	1:10.95
Time	1:10.95
Discharge	1:157,744
Roughness (Manning's n)	1:2.22

#### Appurtenances

13. Water was supplied to the models by a comprehensive circulating water-supply system, and discharges were measured with venturi meters. Water-surface elevations were measured with piezometer gages located in the model channels as shown in Figures 2 and 3 and special gages as required. Velocities and current directions were determined in the model with wooden cylinder floats weighted on one end to simulate the maximum permissible draft for loaded barges using the waterway (9 ft prototype).

14. Model towboats with tows (Figure 4) were used to determine and demonstrate the effects of currents on tows approaching and leaving the locks. The towboats were equipped with two screw-type propellers powered by two small electric motors operating from batteries located in the tow. The rudders and speed of the tows were remote-controlled. The model towboats could be operated in forward and reverse at a speed comparable to that of towboats expected to use the Ohio River waterway.

#### Model Adjustment

15. After construction of the models, roughness of the channel and overbank was adjusted in accordance with available prototype data. The model surfaces were constructed of brushed cement mortar to provide a surface roughness (Manning's n) of about 0.013, which corresponds to a prototype channel roughness of about 0.030. Folded strips of 8-mesh wire screen were placed along the overbank where trees and other vegetation were indicated. Operation of the models with various riverflows indicated that the models reproduced stages very closely.



Figure 4. Remote-controlled towboats and tows in the upper approach at the existing locks

### PART III: DESCRIPTION OF TESTS AND PROCEDURES

16. Tests in the model were concerned primarily with the study of flow patterns, measurements of velocities, different arrangements for auxiliary lock walls, surges in the lock approaches resulting from lock filling and emptying, and the behavior of the model tow in the lock approaches with various riverflows. Since the worst conditions for navigation were obtained in the model during the higher river stages with uncontrolled riverflows, no tests were conducted to determine the effects of dam gate operation other than with flow distributed uniformly over the entire length of the dam.

#### Test Conditions

17. Tests were conducted by reproducing stages and discharges with tailwater elevations based on information furnished by the US Army Engineer District, Huntington:

##### Existing site (mile 279.2)

18. The following conditions were reproduced with the existing conditions:

- a. A controlled riverflow of 75,000 cfs with normal upper pool el 538.0 with tailwater el 522.7.
- b. Maximum flow at which normal upper pool el 538.0 could be maintained (217,000 cfs) with tailwater el 537.0.
- c. An intermediate flow (300,000 cfs) with tailwater el 544.1.
- d. Maximum navigable flow (433,000 cfs) at existing locks with tailwater el 554.8.
- e. Maximum navigable flow (466,000 cfs) at proposed locks with tailwater el 557.5 (based on a freeboard of 2 ft at the locks).
- f. Modified design flood (500,000 cfs) with tailwater el 560.1.

##### Alternate site (mile 282.3)

19. The following conditions were reproduced with the alternate site conditions:

- a. A low flow (75,000 cfs), which would be a controlled flow with the dam in place, tailwater el 522.2.
- b. Maximum flow at which normal upper pool el 538.0 could be maintained (232,000 cfs) with the dam in place, and tailwater el 537.0.
- c. An intermediate flow (300,000 cfs) with tailwater el 542.8.

- d. Maximum navigable flow (465,000 cfs) with lock and dam in place and tailwater el 555.9 (based on a freeboard of 2 ft at the locks).
- e. Modified design flood (500,000 cfs) with tailwater el 558.7.

#### Test Procedures

20. The controlled riverflows were reproduced by introducing the proper discharge, setting the tailwater elevation of the discharge, and manipulating the dam gate openings until the required upper pool elevation was obtained. Uncontrolled riverflows were reproduced by introducing the proper discharge with dam gates fully open and manipulating the tailgate to obtain the proper elevation below the dam. All stages were permitted to stabilize before data were recorded. Current directions were determined by plotting the paths of wooden floats described in paragraph 13 with respect to ranges established for that purpose, and velocities were measured by timing the travel of the floats over known distances. General surface current directions were determined by time exposure photographs recording the movement of confetti on the water surface. During tests with the model tows, the effects of currents on the movement of the tows approaching and leaving locks, drifting or powered, were observed and in some cases recorded by means of multiexposure photographs. Most of the modifications were developed during preliminary tests. Data obtained during these tests were sufficient only to assist in the development of plans that appeared to produce some significant improvements. Results of the preliminary tests are not included in this report.

## PART IV: EXISTING SITE

### Base Test

#### Description

21. The base test was conducted with the conditions that existed at the Gallipolis Locks and Dam at the time the study was undertaken. The purpose of this test was to obtain data that could be used to document conditions existing at the site and to provide a basis for determining the effects of proposed changes on navigation conditions. The principal features of the existing structures included the following (Figure 2):

- a. A nonnavigable gated spillway and locks located in a bend of the river channel at mile 279.2. The locks were along the left (convex) bank with the main lock, adjacent to the bank, having clear chamber dimensions of 600 by 110 ft and the auxiliary lock, on the riverside of the main lock, having clear chamber dimensions of 360 by 110 ft. The main lock had a 1,223-ft-long curved upper guide wall and a 580-ft-long lower guide wall. The auxiliary lock had a 636-ft-long ported upper guard wall and a 450-ft-long nonported lower guard wall. Tops of lock walls were at el 556.0.
- b. The spillway contained eight 125.5-ft-wide gate bays and eight 16-ft-wide piers with gate sills at el 508.5.
- c. A fixed weir, top el 556.0, connected the gated spillway to the right bank.

#### Results

22. Water-surface elevations measured with the various flows tested are shown in Table 1. These results indicate water-surface slopes upstream of the dam (Gages 1-4) were about 0.3 ft per mile with the open riverflows and varied from about 0.3 ft to about 0.6 ft per mile downstream of the dam (Gages 6-8). The drop in water-surface elevations from just upstream of the upper guard wall of the auxiliary lock to just downstream of the dam (Gages 4-6) varied from about 0.7 ft with the 217,000-cfs flow to about 1.1 ft with the 433,000-cfs flow.

23. Results shown in Plates 1-4 indicate that currents approaching the locks were generally straight and parallel to the left bank for a considerable distance upstream but then crossed toward the riverside of the upper guard wall of the auxiliary lock a short distance upstream of the wall. There was some flow toward the lock side of the guard wall of the auxiliary lock, but

the amount was generally small. A counterclockwise eddy formed in the upper lock approach between the guard wall of the auxiliary lock and the guide wall of the main lock. Maximum velocities of the currents moving across the upper lock approach varied from about 1.2 fps with 75,000-cfs flow to as much as 7.6 fps with the 433,000-cfs flow. Velocities along the left bank upstream were somewhat higher. Flow through the dam moved toward the left bank across the lower lock approach. A counterclockwise eddy formed in the lower approach and increased in size with increase in discharge. Velocities in the eddy with open riverflows were as much as 2.2 fps. Velocities of currents along the left bank downstream of the eddy were generally lower than along the bank in the upper approach. However, velocities of the currents moving toward the left bank just downstream of the end of the lower guard wall of the auxiliary lock were generally high, varying from about 6.2 to 6.7 fps with uncontrolled riverflows.

24. Due to the crosscurrents in the upstream lock approach and the alignment of a downbound tow making the turn toward the locks, navigation conditions were extremely difficult and hazardous, particularly with the higher flows. Downbound tows approaching the locks from along the left bank would tend to be moved riverward as they approached the end of the upper guard wall of the auxiliary lock (Photo 1). When the tow would attempt to turn into the lock approach, the stern and port side of the tow would be exposed to the high-velocity currents moving along the bank, which would tend to rotate the tow counterclockwise. Large tows without special steering devices would have to attach mooring lines on the guide wall to enter the locks, particularly during the higher flows. Upbound tows with sufficient power to overcome the effects of the crosscurrents should not experience any serious difficulties in leaving the locks.

25. Navigation conditions in the downstream lock approach were considerably better than conditions in the upper lock approach. However, some maneuvering would be required for upbound tows to make a satisfactory landing on the guide wall of the landside lock. Upbound tows approaching the landside lock from along the left bank would have to make a turn toward the guide wall and could hit the guard wall or center wall with considerable impact, particularly during the higher flows (Photo 2). No difficulties were indicated for downbound tows leaving the locks.

## Plan E

### Description

26. Plan E involved modifications designed to improve navigation conditions in the approaches to the existing locks. The plan included the construction of five submerged dikes in the upper lock approach with top el 524.0, fill placed between the cells and left bank to el 556.0, and a wing dike angled 18 deg riverward and extending from the end of the lower guard wall with top el 540.0 (Figure 5).

### Results

27. Except for an increase of about 0.1 ft opposite the submerged dikes (Gage 4) with the 217,000-cfs flow, the modifications of Plan E had little effect on water-surface elevations. Current directions and velocities shown in Plate 5 indicate a considerable reduction in the velocity of the currents near the left bank in the vicinity of the submerged dikes and in the intensity of the crosscurrents near the end of the upper guard wall of the auxiliary lock. The velocities in the immediate approach to the locks ranged from less than 1.0 fps to about 6.8 fps with riverflows of 75,000 cfs and 433,000 cfs, respectively, as compared to 1.2 fps and 7.6 fps for base conditions. The size of the eddy in the lower approach to the locks was increased and the velocities along the left bank downstream of the approach were reduced somewhat. Velocities in the eddy moving riverward near the lower end of the guard wall were generally less than for base conditions.

28. Navigation conditions for downbound tows approaching the locks were improved compared with existing conditions, particularly during the lower flows. However, downbound tows would continue to experience some difficulties because of the need for the tows to make the turn to become properly aligned to enter the lock chamber (Photo 3). Navigation conditions for upbound tows approaching the lock were also improved (Photo 4). No difficulties were indicated for tows leaving the locks in either direction, although upbound tows would require sufficient power to overcome the effects of currents in the upper lock approach.

## Plan E-1

### Description

29. Plan E-1 involved the replacement of the existing locks with two

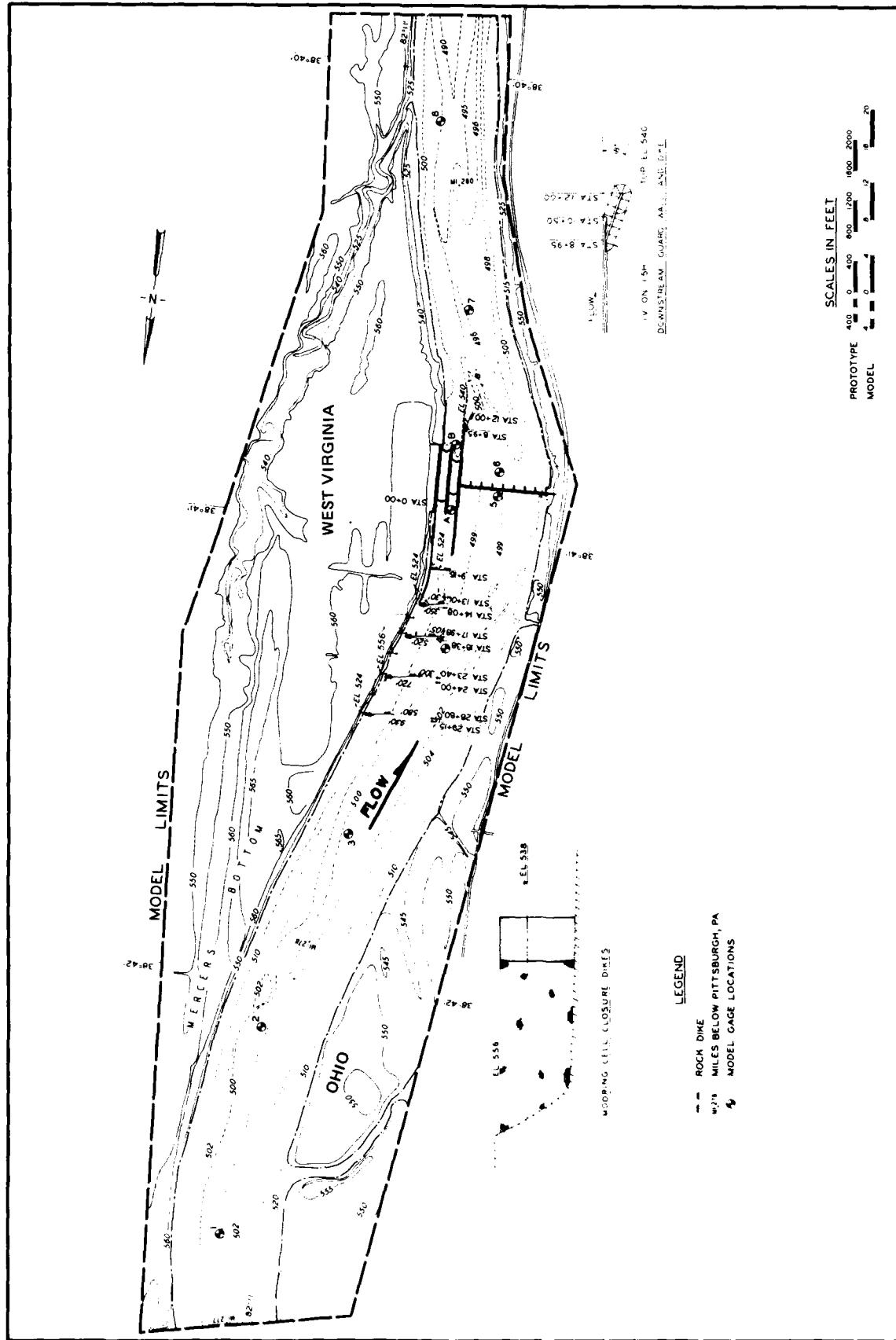


Figure 5. Plan E

1,200- by 110-ft locks located in a bypass canal along the left overbank, thereby increasing the maximum navigable flow to 466,000 cfs. The essential features of this plan, shown in Figures 6 and 7, included the following:

- a. Two adjacent locks with a common center wall each having clear chamber dimensions of 110 by 1,200 ft located in a bypass canal through the left overbank. The lock on the left side of the canal had guide walls that extended 665 ft upstream of the upper lock gate pintle and 600 ft downstream of the lower gate pintle. The guide walls for the lock on the right side extended 1,265 ft upstream of the upper lock gate pintle and 1,200 ft downstream of the lower gate pintle. Tops of the lock walls were at el 560.0.
- b. The bypass canal was about 1.8 miles long and excavated to a bottom el 520 upstream of the locks and el 500 downstream of the locks. The canal upstream of the locks had a minimum width of 300 ft. Excavation along the left bank extended about 7,200 ft upstream of the upper lock gate pintles in a straight line parallel to the lock walls. The canal right bank angled riverward from the end of the guide wall of the riverside lock and tied into the existing riverbank about 2,300 ft upstream of the lock upper gate pintle. In the downstream approach, the excavation along the left bank extended 2,000 ft downstream of the guide wall along a line parallel to and 185 ft landward of the center line of the landside lock, then making a transition with the existing bank line. The excavation on the right side extended riverward to the end of the lower guide wall of the existing main lock.
- c. The material excavated from the canal was placed along the left overbank adjacent to the canal.
- d. Lock filling intakes were located in the lock walls upstream of the lock gates.

#### Results

30. The installation of the canal with the new locks had no significant effect on water-surface elevations in the reach. Velocities near the left bank in the upper approach to the existing locks were somewhat lower than with the base test due to the effects of the canal entrance on flow moving along the left bank toward the existing locks (Plates 6 and 7). The maximum velocities in the upper approach to the existing locks were about 5.5 to 7.7 fps with the 217,000- and 433,000-cfs flows, respectively. Strong crosscurrents developed near the upstream entrance to the canal with velocities ranging from about 2.7 fps with the 217,000-cfs flow to 4.2 fps with the 466,000-cfs flow. A counterclockwise eddy formed in the canal entrance which increased in size and intensity as discharge increased. Maximum upstream velocities were about

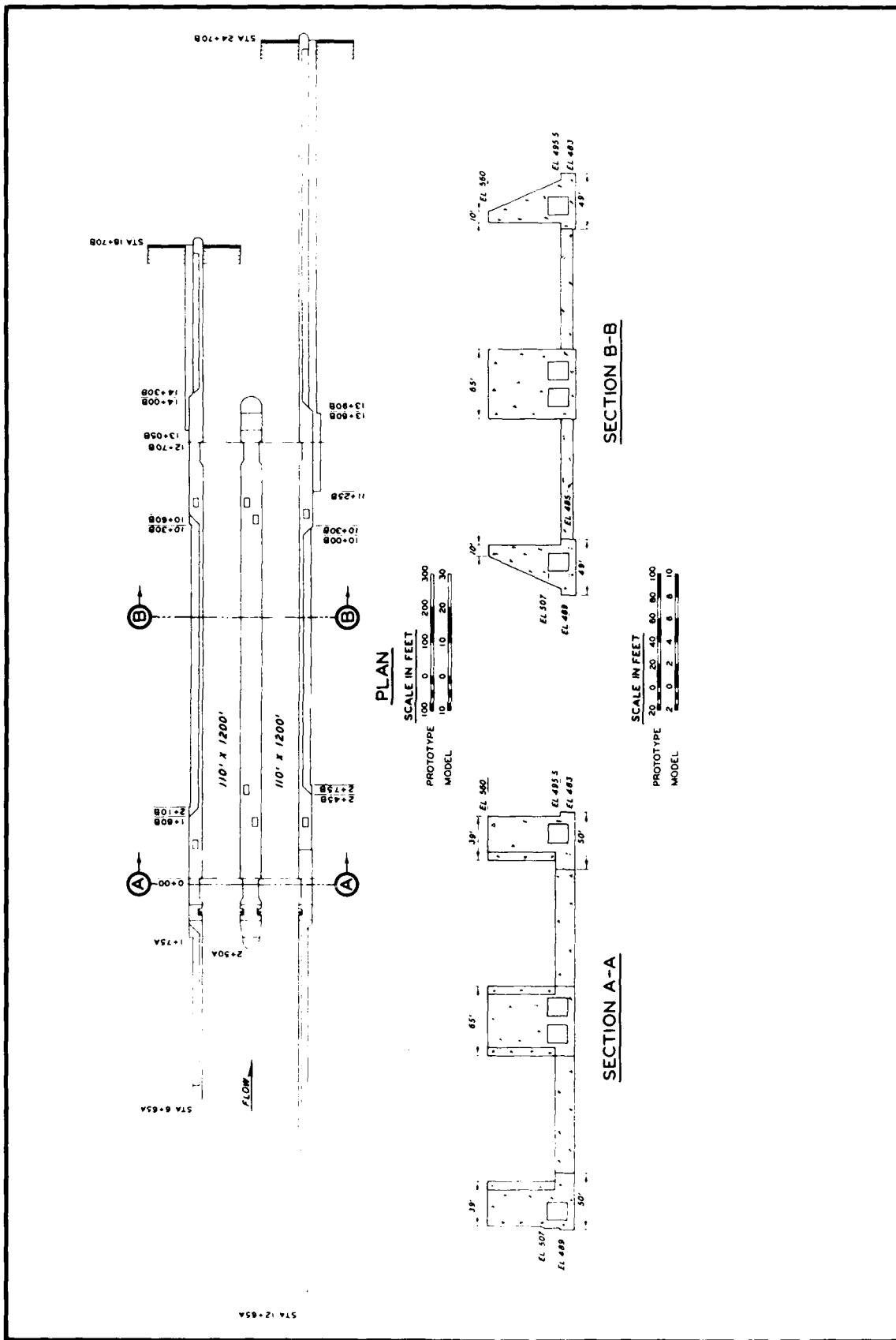


Figure 6. Plan E-1, plans and sections of proposed locks

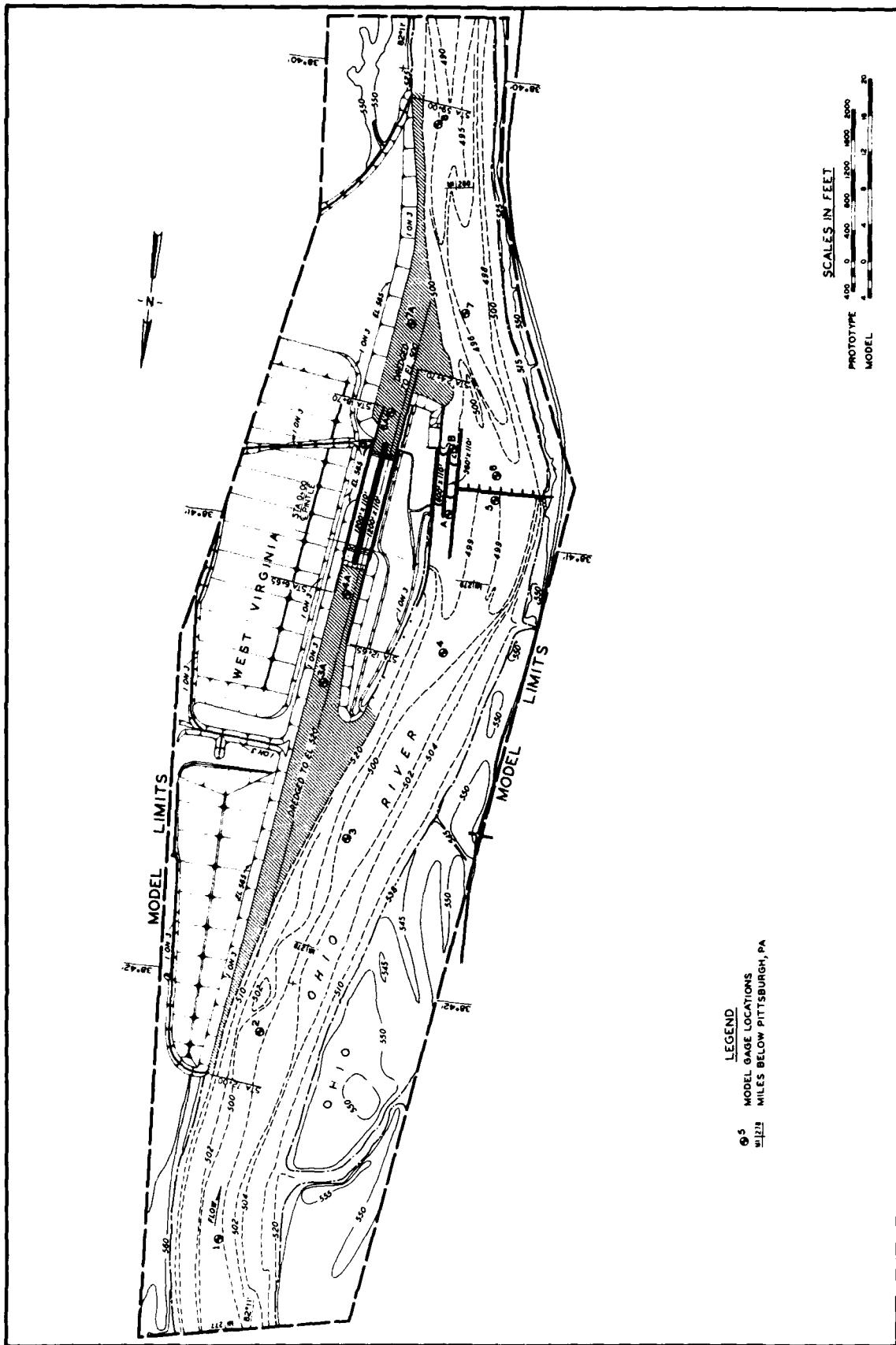


Figure 7. Plan E-1

1.6 fps and occurred with the 466,000-cfs flow (Plate 8).

31. A large counterclockwise eddy formed in the lower approach to the existing locks and extended downstream across the lower approach to the proposed locks. Currents downstream of the eddy moved toward the excavated left bank at a rather sharp angle with maximum velocities in the approach to the new locks varying from about 3.3 fps with the 217,000-cfs flow to about 6.3 fps with the 466,000-cfs flow.

32. Due to the crosscurrents near the upstream entrance to the canal, downbound tows approaching the canal would tend to be moved riverward of the canal entrance when attempting to enter the canal. Downbound tows approaching the new locks would have to maintain sufficient power and speed to overcome the effects of the currents at the canal entrance and then reduce speeds before reaching the lock guide wall. Because of the effects of the currents at the canal entrance, some maneuvering would be required for the downbound tow to become properly aligned with either of the lock guide walls. Lock filling from the canal would produce surges in velocities and water-surface elevations that could be hazardous for downbound tows approaching the locks. Two-way traffic in the upper lock approach would tend to be hazardous with the higher flows, even without lock filling. In the lower approach to the new locks, upbound tows would be adversely affected by currents moving toward the left bank and currents in the counterclockwise eddy. Upbound tows could approach the guide wall on either of the new locks but would tend to be moved away from the walls before becoming properly aligned for entrance into the lock. Considerable maneuvering and possibly the attachment of mooring lines on the wall might be required for a satisfactory entrance into the locks. No difficulties were indicated for tows leaving the locks in either direction.

#### Plan E-2

##### Description

33. Plan E-2 included modifications designed to improve navigation near the entrance to the bypass canal and in the lock approaches. This plan was the same as Plan E-1 except for the following (Figures 8 and 9):

- a. The upper guide walls on the locks were replaced with short wing walls. The lock center wall was extended upstream 1,110 ft to sta 13+60 to form a common guide wall for both

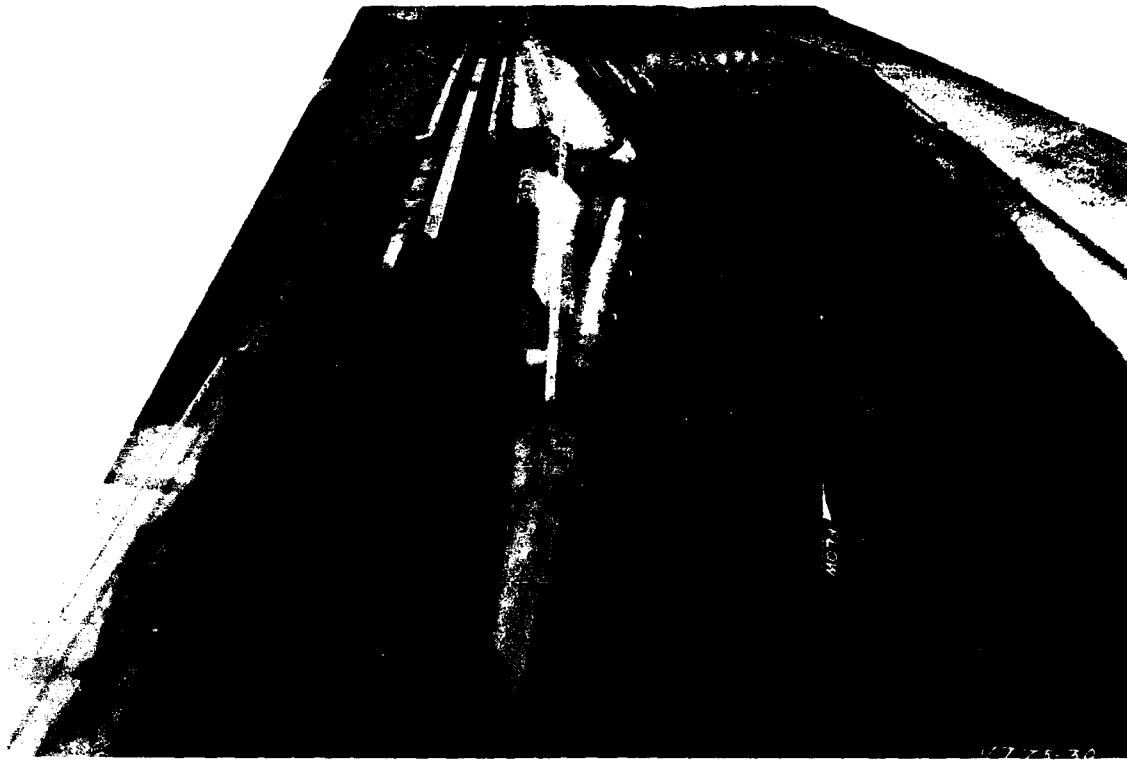


Figure 8. Plan E-2 channel configuration

locks. The lower guard wall on the riverside lock was extended downstream 135 ft.

- b. The bypass canal was excavated to provide a 500-ft bottom width upstream approach to the new locks, and a channel with a 50-ft bottom width was excavated to el 520 through the island between the bypass canal and the river. The island was extended upstream about 900 ft.
- c. The intakes for lock filling were located in the left bank of the river channel just upstream of the upper guide wall of the existing main lock.

#### Results

34. The alignment of the currents near the upstream entrance of the canal was improved considerably by flow entering the canal and moving riverward through the 50-ft channel excavated through the island (Plates 9-11). Crosscurrents were practically eliminated with the 75,000- and 217,000-cfs flows and reduced considerably with the 466,000-cfs flow. Flow in the upper end of the canal was concentrated mostly along the right side with an eddy of low intensity forming along the left side. Maximum velocity of currents within the canal varied from about 1.7 to 2.9 fps with the higher velocities occurring close along the right bank. The maximum velocity through the

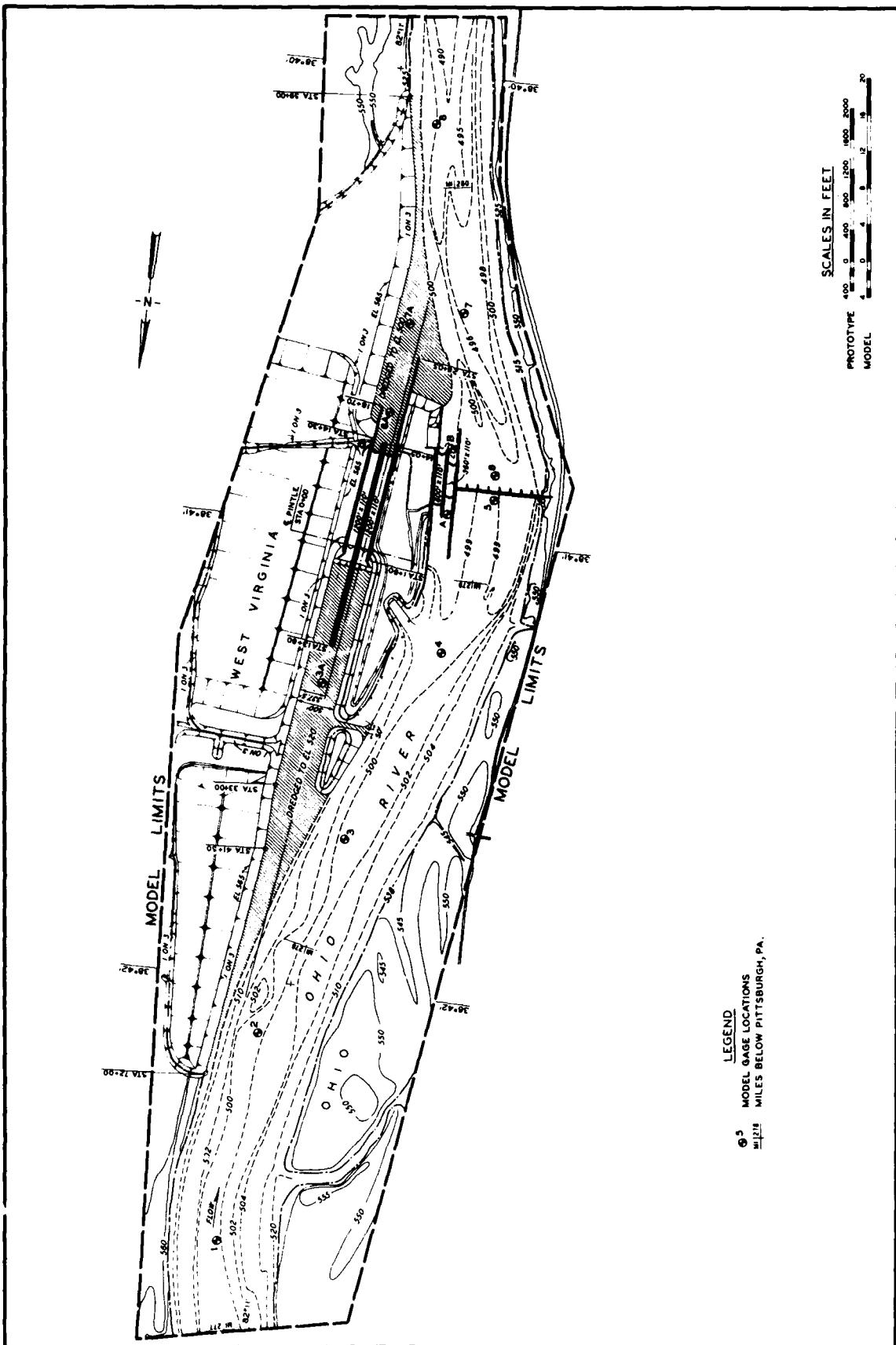


Figure 9. Plan E-2

channel across the island was about 5.4 fps and occurred with the 466,000-cfs flow. There was little change in the currents in the lower lock approach except for the effect of the extended guide wall on the shape of the eddy.

35. Navigation conditions for downbound tows were considerably better than with Plan E-1 with all flows tested. Because of the decrease in the intensity of the crosscurrents, downbound tows could make a satisfactory entrance into the canal with less power and steerage. Tows could reduce speed to approach the guide wall for entrance to either lock without any serious difficulties. Tows moving close along the right bank of the canal with little headway would tend to be moved toward the bank by flow through the 50-ft channel across the island. The effects of the currents were generally small and could be easily overcome by maintaining some power on the tow or by moving a short distance from the right bank. Although two-way traffic could be maintained in the upper approach to the new locks, conditions could be improved by realigning the left bank of the canal to eliminate the bend. Navigation conditions for upbound tows approaching the new locks were about the same as with Plan E-1. Some maneuvering would be required to become aligned with the guide walls, and there would be a tendency for the head of tows to be moved from the guide walls as they approached the locks, as in Plan E-1. Because of the maneuvering required, two-way traffic in the lower lock approach would not be feasible. No difficulties were indicated for tows leaving the locks in either direction.

### Plan E-3

#### Description

36. Plan E-3 was designed to improve navigation conditions and provide for two-way traffic in the lower lock approach. This plan was the same as Plan E-2 except for the following (Figure 10):

- a. The lower guide wall on each lock was replaced with a 466-ft-long wing wall angled 15 deg away from the lock approach.
- b. The common center lock wall was extended downstream 1,200 ft to sta 26+05 to be used as a guide wall for both locks similar to the guide wall in the upper approach.
- c. The excavation at the lower end of the island was modified as shown in Figure 10 to accommodate the wing wall.

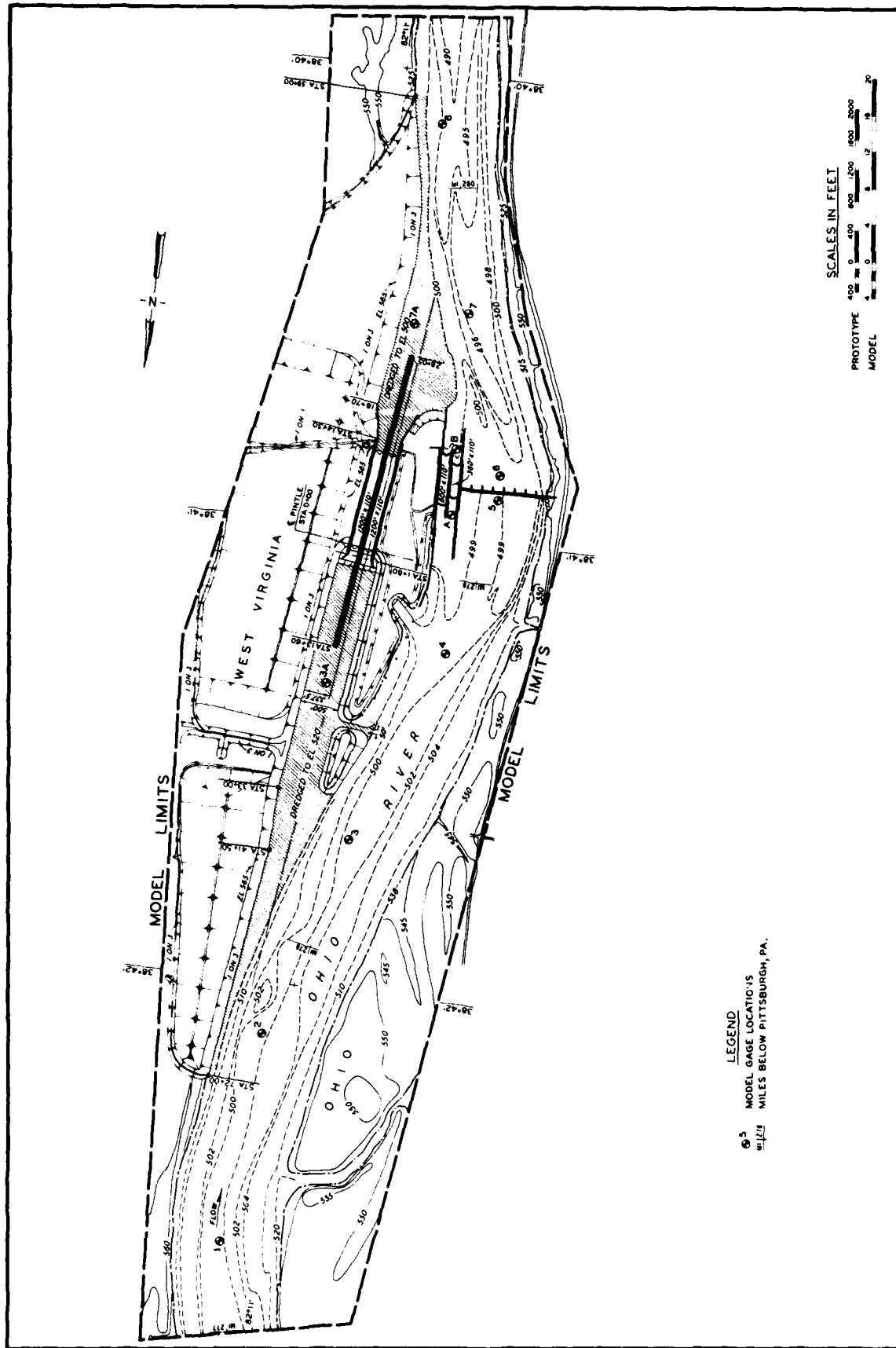


Figure 10. Plan E-3

### Results

37. Current directions and velocities in the lower lock approach shown in Plate 12 indicate little change from those obtained with Plan E-2. The eddy in the lower approach was somewhat larger, but the intensity of the eddy was not changed appreciably. The alignment of the currents moving toward the left bank and in the eddy were not as irregular as with Plan E-2. Maximum velocities in the eddy moving across the lock approach near the end of the lower guide wall varied from less than 0.5 fps with the 75,000-cfs flow to 1.2 and 1.7 fps with the 217,000- and 466,000-cfs flows, respectively.

38. There were no appreciable changes in navigation conditions in the downstream approach to the new locks. Tows could approach the guide wall from either side without difficulty. However, the tendency for the head of tows to be moved away from the guide wall as they approached the locks was not eliminated. With the separation provided by the common guide wall, two-way traffic could be maintained in the lower approach to the locks. Results indicate that navigation conditions for upbound tows approaching the landside lock could be improved by increasing the excavation along the left bank to eliminate or reduce the bend in the left bank line downstream of the wing wall. No difficulties were indicated for downbound tows leaving either lock.

### Plan E-4

#### Description

39. Plan E-4 was based on the use of the existing locks with one large lock in the bypass canal. The principal features of this plan were the same as Plan E-3 except for the following modifications (Figure 11):

- a. The lock on the landside of the bypass canal and the extensions of the upper center lock wall were eliminated and a 1,200-ft-long upper guide wall was added on the right side of the remaining lock. A 750-ft-long wing wall angled riverward 15 deg was provided at the lower end of the right lock wall.
- b. The right bank of the upper approach of the bypass canal was shifted toward the left 90 ft and tied into the end of the upper guide wall. The left bank of the bypass canal was modified by placing the toe of the slope 337.5 ft landward of the lock center line at a point opposite the end of the upper guide wall and extending it parallel to the lock center line upstream to sta 61+50 from where it angled riverward to the river channel.

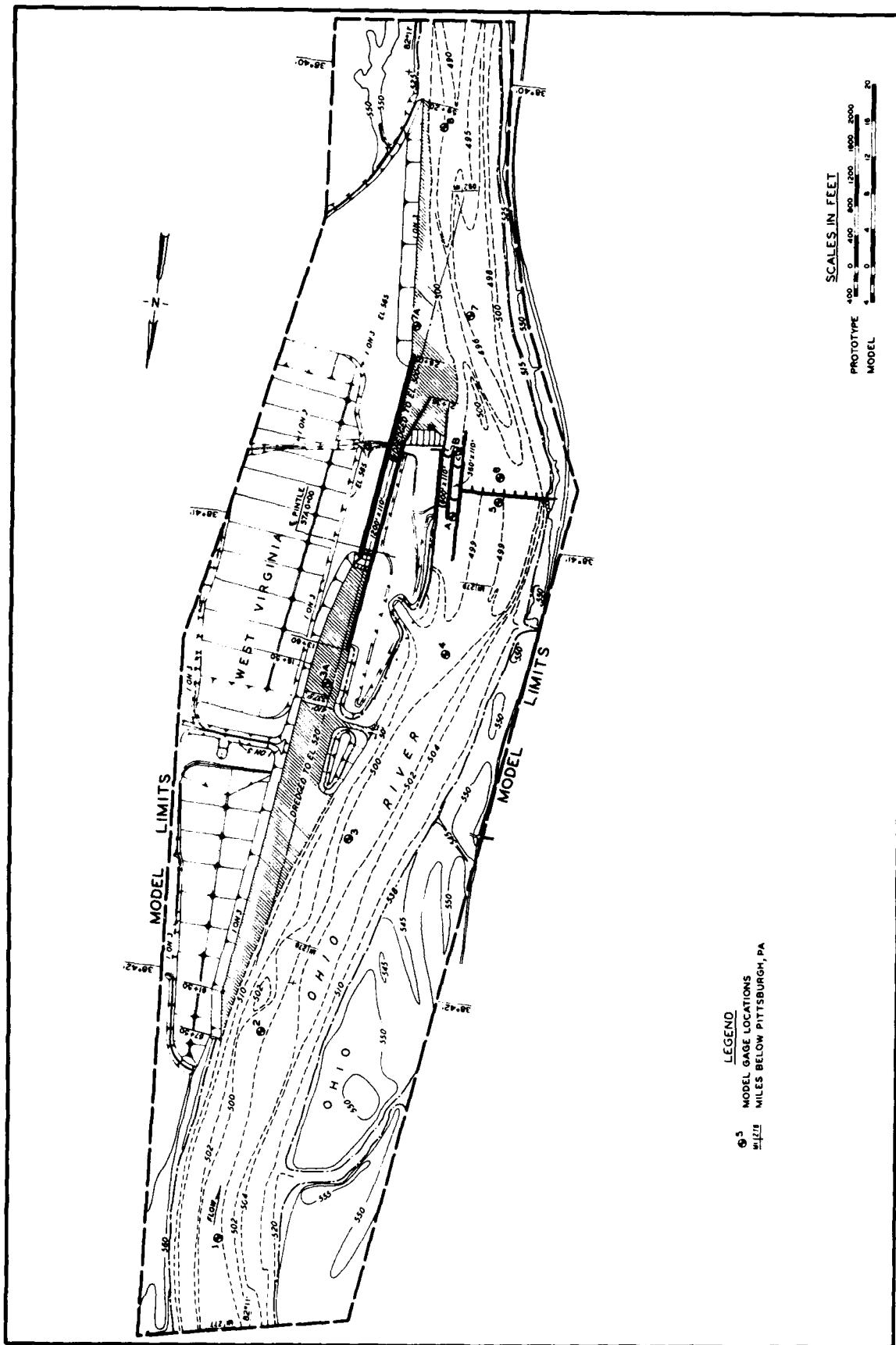


Figure 11. Plan E-4

- c. The excavation along the left bank downstream of the lock extended from the end of the lower guide wall in a straight line for about 3,300 ft tying into the existing bank line.

#### Results

40. Current directions and velocities shown in Plates 13 and 14 indicate a reduction in the amount of flow entering the canal with the 75,000- and 217,000-cfs flows compared with Plan E-2. Because of the decrease in the flow into the canal, there was an increase in the cross currents moving riverward from along the left bank in the approach to the canal. The eddy along the left bank of the canal did not extend as far upstream as in Plan E-2. Velocities of currents moving into the canal and through the 50-ft channel across the island were generally less than with Plan E-2. Maximum velocities in the approach about 1,000 ft upstream of the canal entrance varied from about 3.8 to 5.6 fps with the 300,000- and 433,000-cfs flows (Plates 15 and 16). There were no major changes in the current patterns in the upper approach to the existing locks. Changes in the lower approach to the new lock were generally small compared with Plan E-3. The size of the eddy was somewhat smaller, attributed mostly to the reduction in the excavation along the left bank. The maximum velocity of currents moving toward the left bank across the lock approach varied from about 4.5 fps with the 75,000-cfs flow to about 7.3 fps with the 433,000-cfs flow.

41. No serious difficulties were indicated for downbound tows approaching and entering the canal with the flows tested. Tows would have to approach the canal within about 300 ft of the left bank (Photo 5). Navigation conditions for downbound tows approaching the existing locks were not affected appreciably and would continue to be difficult and hazardous with the higher flows. Because of the alignment of the left bank with respect to that of the lower guide wall and the effects of the currents moving toward the bank, upbound tows would have to approach the new lock from a considerable distance riverward of the bank to avoid considerable maneuvering (Photo 6). Installation of the new lock had little effect on navigation conditions in the lower approach to the existing locks except that upbound tows approaching the new lock could interfere with traffic using the existing lock.

Plan E-5

Description

42. Plan E-5 was the same as Plan E-4 except for modification of the lock auxiliary walls and excavation within and downstream of the bypass canal. This plan involved the following changes (Figure 12):

- a. The upper guide wall was moved to the left side of the lock and the lower guide wall was moved to the right side of the lock.
- b. Excavation along the left bank of the canal upstream of the lock was modified to tie in with the end of the upper guide wall and along the right bank to tie in with the riverside lock wall as shown in Figure 12. Excavation along the left bank downstream of the lock was increased to tie in with the lower end of the landside lock wall.

Results

43. Current directions and velocities shown in Plate 17 indicate some change in the size of the eddy in the upper approach to the new lock, some increase in velocities near the entrance to the canal, and some increase in flow through the 50-ft channel across the island compared with Plan E-4. Conditions in the upper approach to the existing locks were not affected by the modifications within the canal. Conditions in the lower lock approaches were about the same as obtained with Plan E-4 except for changes in the size and shape of the eddy as affected by modifications of the lower guide wall on the new lock (Plate 18).

44. Downbound tows with Plan E-5 could enter the bypass canal and approach the upper guide wall without serious difficulties. However, some maneuvering would be required to properly align the tow as it approaches the upper guide wall (Photo 7). Tows drifting slowly or stopped close along the right bank of the canal could be affected by flow through the 50-ft channel across the island. Because of the need for some maneuvering, navigation conditions in the upper lock approach with this plan were not as good as with Plan E-4. Navigation conditions in the upper approach to the existing locks were not affected by this plan. Navigation conditions in the lower approach to the new lock were considerably better than with Plan E-4. Tows could approach the guide wall from along the left bank or from some distance riverward with little or no maneuvering (Photo 8). The guide wall on the riverside of the new lock provided a separation of traffic between the approaches to the new and existing locks.

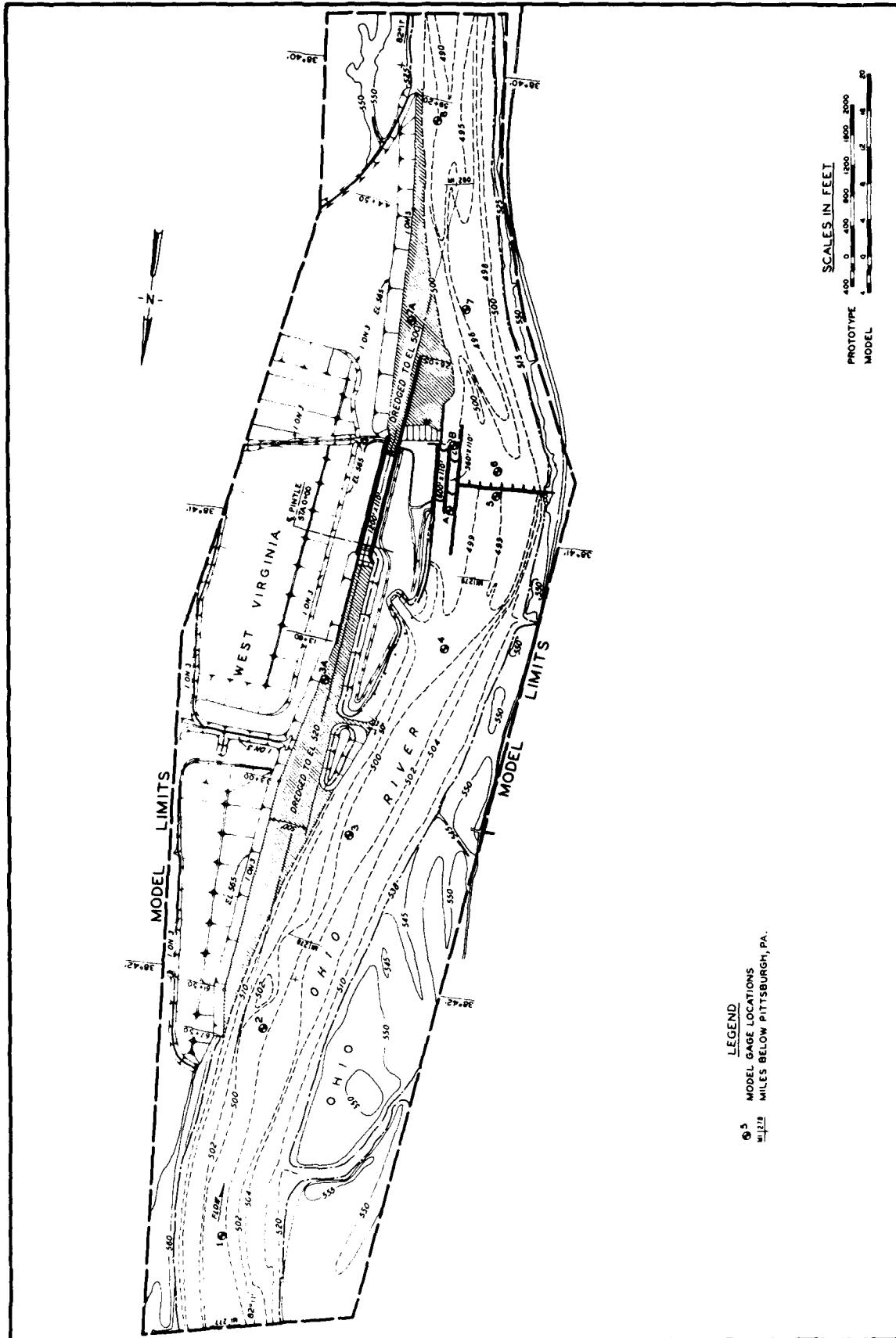


Figure 12. Plan E-5

45. Conditions in the lower approach to the existing locks were about the same as with the other plans tested. No unusual difficulties were indicated for tows entering or leaving the locks.

#### Plan E-6

##### Description

46. Plan E-6 was designed to improve navigation conditions in the approaches to the new lock (Figure 13). This plan consisted of combining the best features of Plans E-4 and E-5. The upstream approach to the new lock was about the same as E-4 except the excavation along the left bank was extended upstream to sta 90+00, reducing the angle of intersection between the canal and river channel. The downstream approach was about the same as Plan E-5. Maximum navigable flow was 466,000 cfs (based on proposed lock in place); however, navigation through the existing locks was to be maintained as long as practical.

##### Results

47. Current direction and velocities in the lower approach to the locks shown in Plate 19 indicated that a slow clockwise eddy would tend to form between the guard wall and the left bank and a large counterclockwise eddy would form in the approach to the lock about the same as in Plan E-5. Maximum velocities of currents moving toward the left bank across the lock approach ranged from about 3.7 fps with the 75,000-cfs flow to about 9.1 fps with the 466,000-cfs flow. Current direction and velocity data were not recorded in the upstream approach to the locks with this plan.

48. Based on observation of the movement of the model tow, navigation conditions in the upper approach to the new lock were improved considerably compared to conditions obtained with Plan E-4. The additional left bank excavation near the upstream end of the canal allowed downbound tows to approach the canal entrance with better alignment than with Plan E-4. Downbound tows could approach and enter the canal and lock without difficulty even when moving a considerable distance off the left bank during the approach to the canal. Navigation conditions in the upper approach to the existing lock were about the same as with Plan E-4. Conditions would continue to be difficult and hazardous, particularly for downbound tows approaching the locks. Navigation conditions in the lower approach to the new lock were about the same as

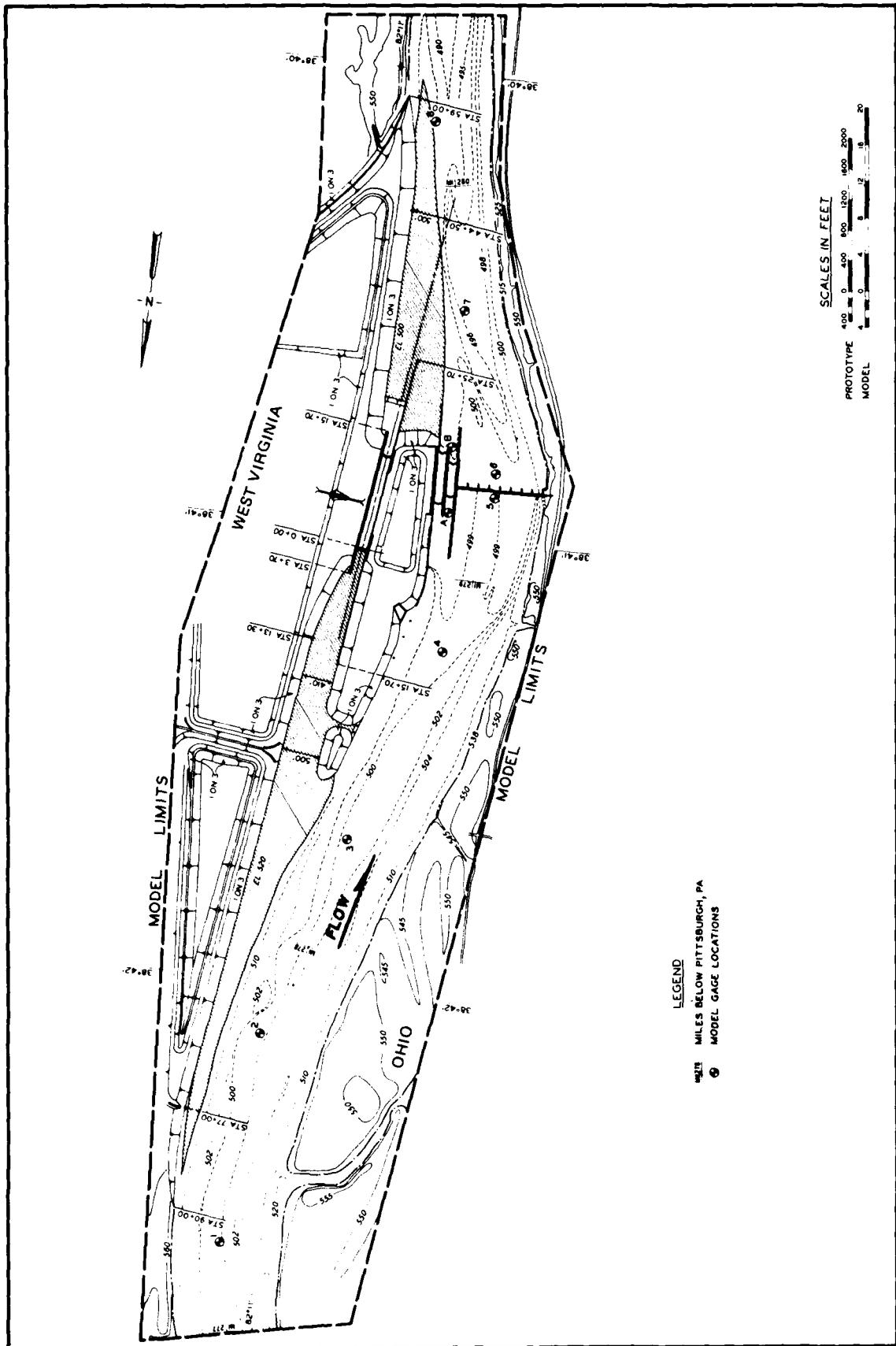


Figure 13. Plan E-6

with Plan E-5. There were no major difficulties for tows entering or leaving the lock. Upbound tows could approach the lock from along the left bank or from near midchannel without difficulty. Navigation conditions in the lower approach to the existing locks were not affected by this plan. Tows could enter and exit the locks without any unusual difficulties.

#### Plan E-7

##### Description

49. Plan E-7 was about the same as Plan E-6 except a second lock with clear chamber dimensions of 110 ft wide and 600 ft long was located to the left and adjacent to the 1,200-ft lock in the canal. The common center lock wall served as a guide wall in the approaches to the new 600-ft lock (Figure 14).

##### Results

50. Current direction and velocities shown in Plates 20-23 compared with those of Plan E-4 indicate some changes in current patterns in the upstream approach to the new locks. The eddies that formed in the canal extended further downstream nearer the locks; however, flow into the canal and through the 50-ft channel across the island tended to be reduced. Generally the current alignment in the upper approach to the canal was straight and parallel to the left bank line with maximum velocities ranging from about 1.9 fps with the 75,000-cfs flow to about 6.1 fps with the 466,000-cfs flow. Conditions in the lower approach to the new locks were about the same as with Plan E-6 except for small changes in the size and shape of the eddies that formed in the lock approach. These changes were attributed to the changes in excavation along the left bank line downstream of the locks. Velocity of the current moving toward the left bank riverward and downstream of the eddy varied from about 3.7 fps with the 75,000-cfs flow to about 8.4 fps with the 466,000-cfs flow.

51. Navigation conditions in the upper approach to the new locks were improved considerably compared with Plan E-4. Downbound tows could approach and enter the bypass canal without any special maneuvering from as much as 600 ft off the left bank about a mile upstream of the entrance with most controlled flows and within 300 ft of the left bank during open riverflows. Downbound tows could approach either lock without difficulty (Photos 9 and

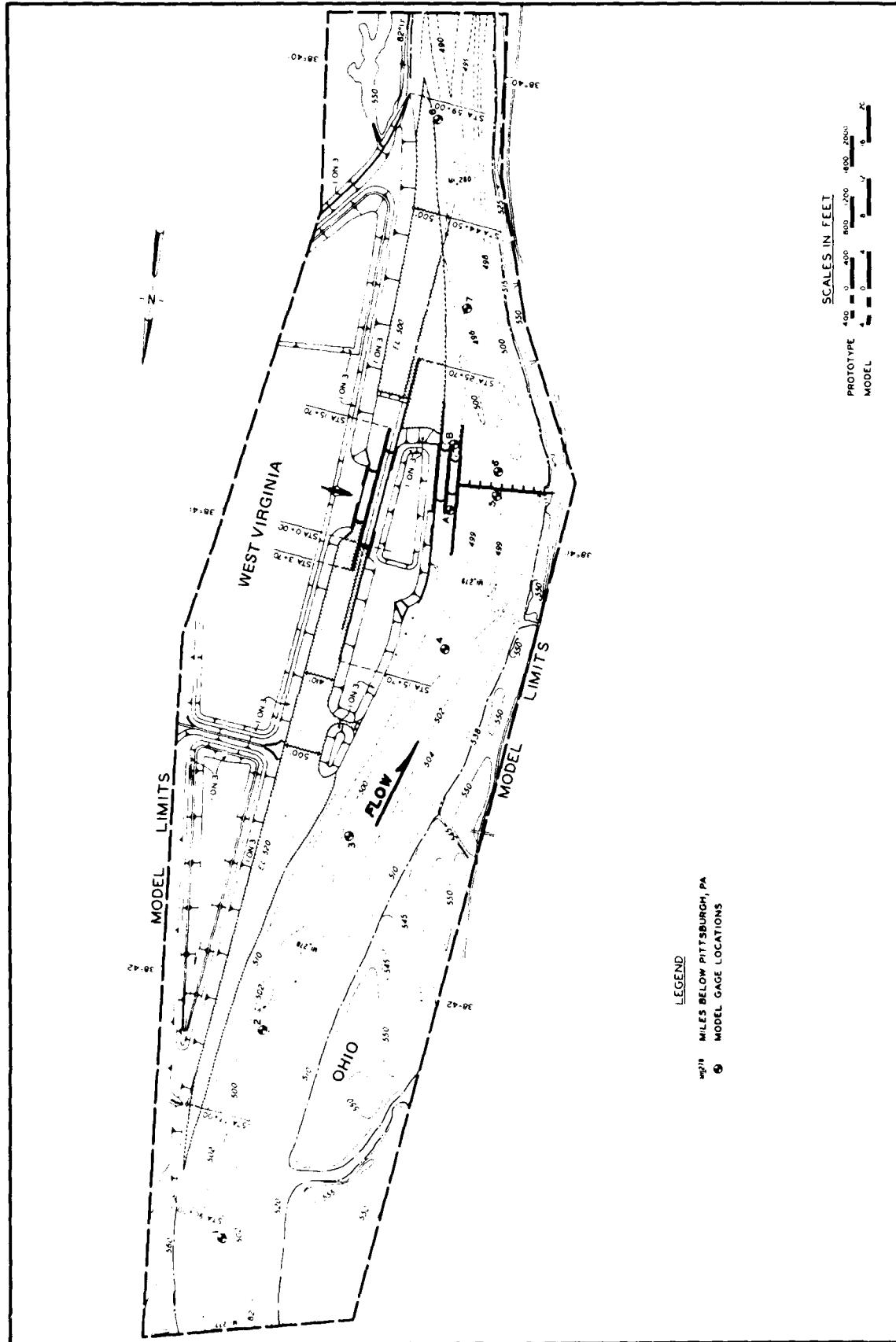


Figure 14. Plan E-7

10). However, based on observations of the model tow, slightly more maneuvering would be required to enter the 600-ft lock than the 1,200-ft lock. Upbound tows could leave either lock and enter the river channel without difficulty. Flow through the 50-ft channel across the island in the upper approach had very little effect on downbound tows and could easily be overcome by moving 100 ft from the right bank of the canal. Navigation conditions in the lower approach to the new locks were satisfactory; tows could approach either lock without difficulty (Photos 11 and 12). Upbound tows could approach the locks from along the left bank line or from near midchannel without difficulties. However, upbound tows approaching the 600-ft lock would require less maneuvering by approaching the lock from 200 to 300 ft off the left bank. Tows could leave the locks upstream or downstream without serious difficulties. Two-way navigation could be maintained in the lock approach provided caution was exercised during the period when the tows were passing (Photos 13 and 14).

52. Navigation conditions in the approaches to the existing locks were about the same as with Plan E-6.

#### Plan E-8

##### Description

53. Plan E-8 (Figure 15) was the same as Plan E-7 except the bottom of the upstream lock approach canal was lowered to el 506.0 to facilitate the movement of a maintenance vessel in the upstream lock approach during an emergency when normal pool could not be maintained upstream of the dam. The intake structures located near the upstream end of the existing curved guide wall were moved farther inland to shorten the length of the filling culverts to the new locks. The bottom elevation of the 50-ft channel through the head of the island was left at 520.0. There were no changes downstream of the dam.

##### Results

54. Current direction and velocities shown in Plates 24-27 compared with those obtained with Plan E-7 indicated increased flow along the left bank line upstream of the canal entrance, with a slight increase in velocities. There was also a tendency for the current to be somewhat erratic near the canal entrance. These changes had no appreciable effects on currents downstream of the dam or on water-surface elevations through the reach.

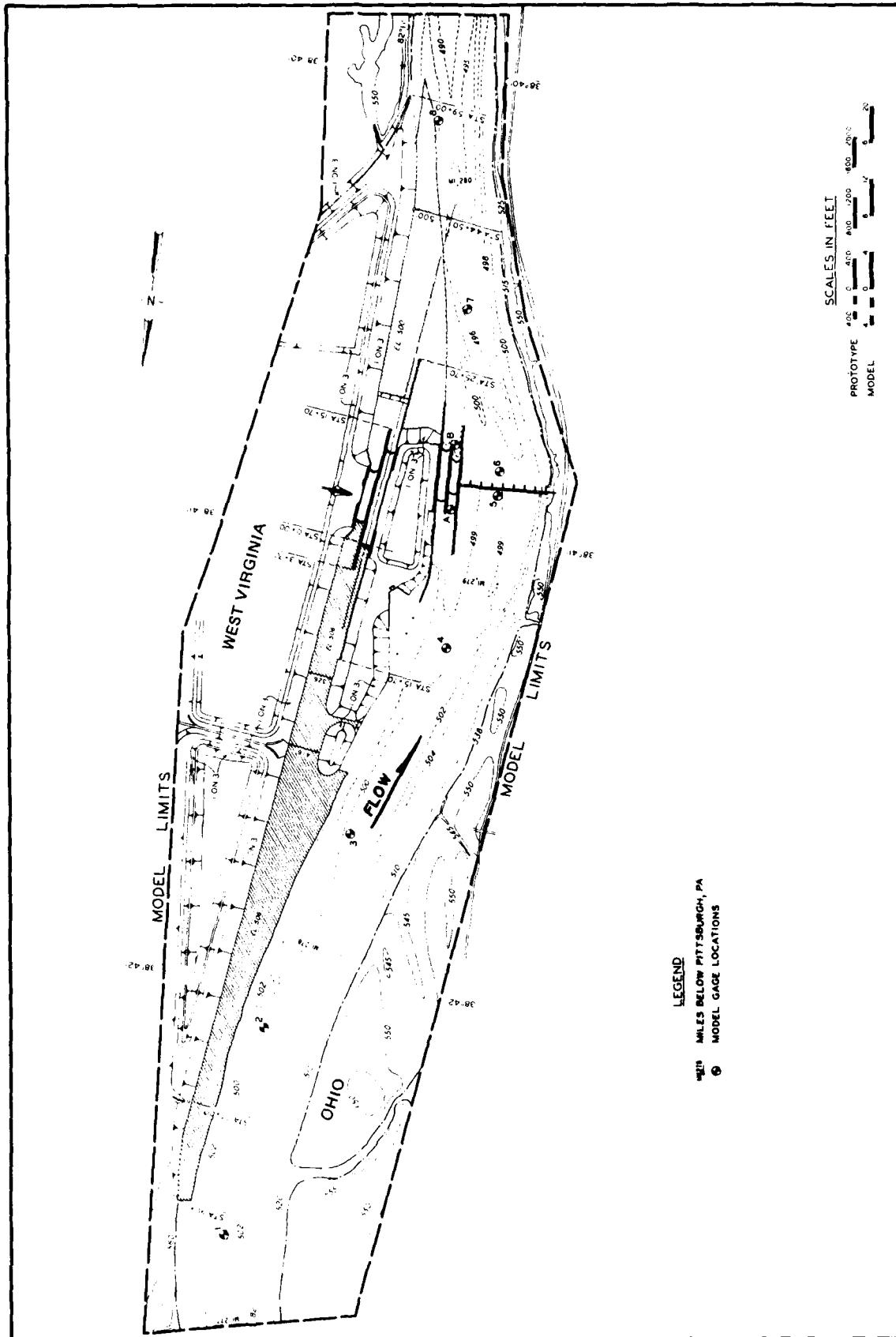


Figure 15. Plan E-8

55. Navigation conditions in the approach upstream of the canal were not as good as with Plan E-7. The effects of the outdraft just upstream of the island were increased considerably. Tows moving in the approach in either direction could be affected adversely due to the outdraft near the canal entrance. Tows moving near the canal entrance with riverflows of 300,000 cfs and greater would have to stay near the left bank to avoid being moved on to the head of the island or riverward of the canal altogether. It would be very difficult and could be hazardous to try to maintain two-way navigation in the upstream approach to the locks with this plan, particularly with the high flows. The large eddy that formed in the intake entrance immediately upstream of the existing locks could adversely affect downbound tows approaching the existing locks.

#### Plan E-9

##### Description

56. This plan was the same as Plan E-8 except that the bottom elevation of the excavation along the left bank upstream of the canal was raised back to el 520 and a low-water emergency entrance for navigation to the canal was provided adjacent to the head of the island (Figure 16).

##### Results

57. The current direction and velocities obtained with this plan are shown in Plates 28-31. A comparison to results obtained with Plan E-8 indicated that the currents would parallel the left bank farther downstream into the approach to the canal, particularly with the higher flows, reducing the effect of the outdraft near the head of the island. The currents appeared to be somewhat more stable near the canal entrance, and in general, the velocities were reduced. This plan had no appreciable effects on water-surface elevations through the reach or on conditions downstream of the dam.

58. Navigation conditions in the upstream approach to the new locks were improved considerably compared to those obtained with Plan E-8 and were very similar to conditions obtained with Plan E-7. Tows could enter or leave the locks without any major adverse effects (Photos 15-18). Note the distance of the tow from the left bank in Photos 15 and 17 and the absence of any erratic changes in the tow alignment as it enters or leaves the canal. Two-way navigation could be maintained to a large extent in the upstream approach to

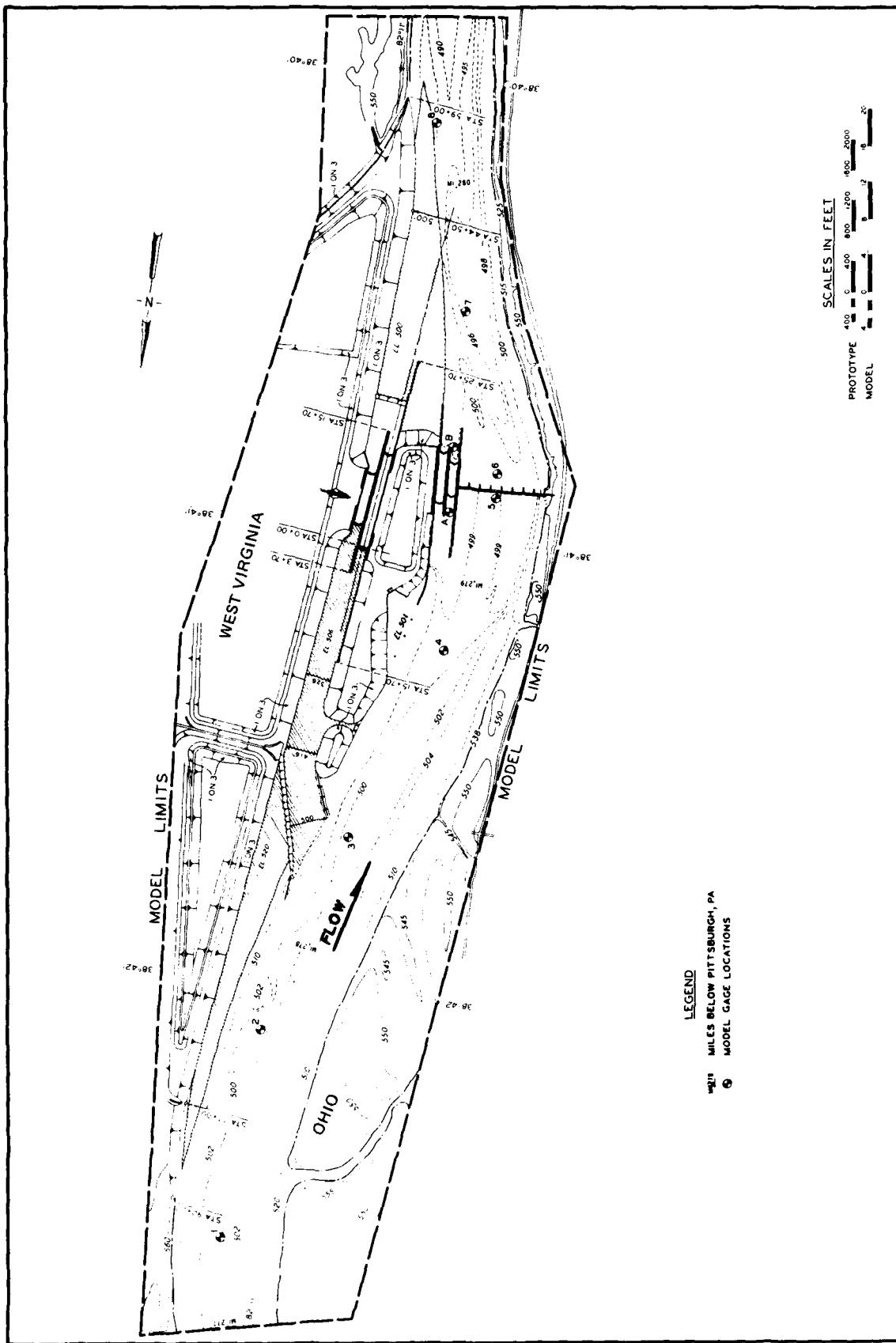


Figure 16. Plan E-9

the locks provided caution was exercised during the time when tows were passing and in the location where passing occurred. Photos 19 and 20, which show the alignment of tows passing in the upper approach to the locks, indicate that there was sufficient area for tows to pass regardless of which lock the downbound tow was approaching. However, slightly more maneuvering would be required for a tow to enter the 600-ft lock than the 1,200-ft lock because of the natural tendency of a downbound tow to move away from the left bank of the canal. Based on this observation, somewhat more tonnage should be able to pass through the locks if the downbound tow used the 1,200-ft lock and the upbound tow used the 600-ft lock. Navigation conditions in the lower approach to the locks were unchanged from those obtained with Plan E-7.

#### Plan E-10

##### Description

59. Plan E-10 was the same as Plan E-9 except that the upstream guard wall on the existing riverward lock was removed and the filling systems for the new locks were located in a channel through the island just upstream of the existing guide wall instead of in the long culvert (Figure 17).

##### Results

60. Current direction and velocities shown in Plates 32-35 compared to the results obtained with Plan E-9 (upstream approach) and Plan E-7 (downstream approach) indicated no significant changes. Current velocities near the upstream entrance to the canal ranged from less than 1.0 fps with the 75,000-cfs flow to about 3.8 fps with the 466,000-cfs flow, while the velocities about 2,000 ft upstream of the canal entrance ranged from about 1.4 fps to 5.5 fps, respectively. Current velocities moving across the lower approach to the new locks ranged from about 2.9 fps with the 75,000-cfs flow to about 6.7 fps with the 466,000-cfs flow.

61. Navigation conditions in the approaches to the new locks were satisfactory with this plan. Upbound and downbound tows could approach, enter, and exit the locks in either direction without any major difficulty with all flows tested. In general there were no appreciable changes in navigation condition with this plan compared to conditions with Plan E-9.

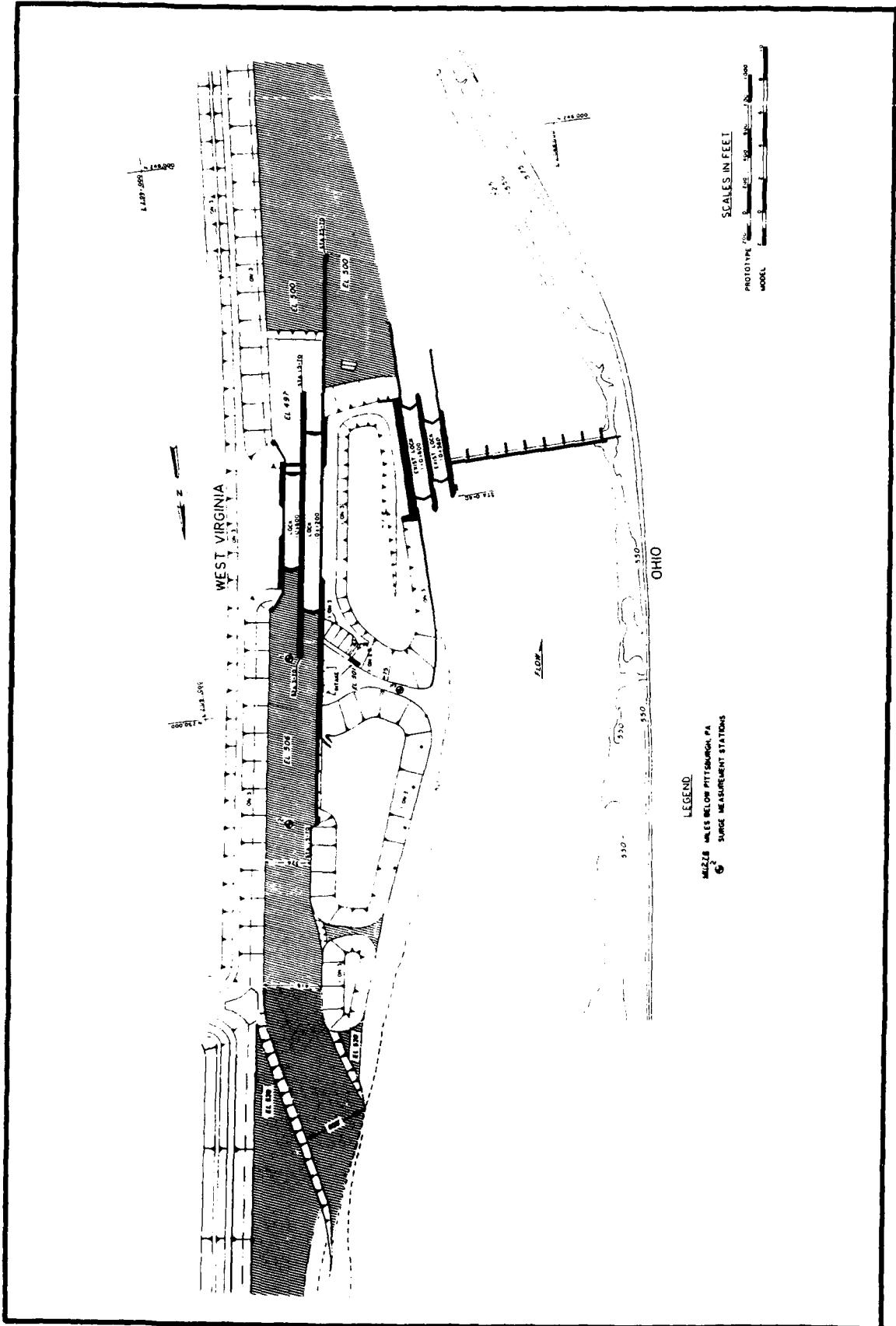


Figure 17. Plan E-10

## PART V: SPECIAL TESTS

### Lock Filling Tests

#### Procedure

62. These tests were conducted to determine the effects on navigation conditions in the upstream approach to the new locks during lock filling with various schemes and with the intake structures at different locations. The riverflows reproduced for these tests ranged from 16,000 to 466,000 cfs. However, the most significant effects resulting from lock filling occurred with the 16,000-cfs flow and a maximum lift at the locks of 23 ft; as the riverflow was increased, the effects of lock filling decreased. Therefore tests involving the maximum effects are reported in more detail than tests with the higher flows. The model tow used during these tests simulated a 15-barge tow with a draft of 9 ft. Current alignment and velocity measurements were obtained with floats submerged 9 ft except when surface current patterns are shown. Surface currents were obtained with confetti. The filling curves reproduced during these tests are shown in their respective plates except for tests of Schemes 1-3, which were based on a lock filling time of 9 min filling only one lock at a time. Before the tests were conducted, the natural variation in water level in the canal caused by pulsating currents and natural changes in the size and intensity of the eddy were recorded.

#### Description of Schemes 1-3

63. The following conditions were tested:
- a. Scheme 1. Tests were conducted with Plan E-1 conditions and involved filling one 1,200-ft lock from the bypass canal through intake culverts located in the lock walls just upstream of the miter gates.
  - b. Scheme 2. Tests were conducted with Plan E-2 conditions and involved filling one 1,200-ft lock through intake culverts located in the riverbank just upstream of the end of the guide wall of the existing landside lock.
  - c. Scheme 3. Tests were conducted with Plan E-4 conditions and involved filling one 1,200-ft lock through intake culverts located along the riverbank (same as for Scheme 2).

#### Results

64. Tests indicated a natural variation in water level in the canal of about 0.1 ft with the 16,000-cfs flow, which increased to about 0.5 ft with

the higher flows, except in Scheme 2, for which the variation was about 0.7 ft with the 466,000-cfs flow (Table 2).

- a. Scheme 1. Surges in the canal during lock filling ranged from about 1.8 ft below normal upper pool to 0.7 ft above with the 16,000-cfs flow with overfilling of the lock of about 0.8 ft (Table 2). With the 217,000- and 466,000-cfs flows, lock filling had little effect on water-surface elevations in the canal with overfilling of the locks of about 0.3 ft. Overfilling of the locks with the higher flows was caused in part by the natural surge in the canal. The maximum surge in the canal occurred with the maximum differential in water level upstream and downstream of the locks, which was 23 ft with the 16,000-cfs flow. Maximum velocities in the upper lock approach with this flow were about 2.8 fps near the lock and about 2.7 fps near the end of the upper guide wall of the riverside lock (Photo 21). A downbound tow would be in danger of hitting the lock wall or being moved into the upper lock gates by these currents. Floating debris and ice would also tend to enter the canal during lock filling with the lower flows. Lock filling with open riverflows had little effect on currents in the canal or on the movement of debris and ice into the lock approach.
- b. Scheme 2. The results shown in Table 2 indicate that filling of either lock with Plan E-2 would have no effect on water-surface elevations in the canal since filling would be from the river rather than the canal as in the previous test. There was a small difference in the natural surge in the canal with the higher flows that could be attributed to the change in configuration of the lock canal. Overfilling of the lock ranged from a maximum of 0.8 ft with the 16,000-cfs flow to 0.1 ft with the 217,000-cfs flow. The differential between the water-surface elevations in the lock chamber and the canal after lock filling varied due to the natural surge in the canal and ranged from a maximum of 0.9 ft with the 466,000-cfs flow to 0.1 ft with the 16,000-cfs flow. Filling the lock had no significant effect on navigation in the canal or on the amount of floating debris and ice that would enter the canal but could move some debris or ice into the lock filling intakes.
- c. Scheme 3. Results shown in Table 2 indicate filling of a single 1,200-ft lock from the river would have no significant effect on water-surface elevations in the canal with Plan E-4 lock canal configuration. There was a slight difference in the natural surge in the canal with the 217,000-cfs flow as compared to Scheme 2, which was attributed to the configuration of the lock canal. Water-surface elevations measured during lock filling with the 16,000-cfs and 217,000-cfs flows were generally the same as with Scheme 2. Overfilling of the lock ranged from a maximum of 0.8 ft with the 16,000-cfs flow to 0.1 ft with the 217,000-cfs flow. The differential between the water-surface elevations in the lock chamber and the canal after lock filling varied due to the natural surge in the canal and ranged from a maximum of 0.6 ft with the 433,000-cfs flow

to 0.1 ft with the 16,000-cfs flow. Filling the lock had no significant effect on navigation in the canal or on the amount of floating debris and ice that would enter the canal but could move some debris or ice into the lock filling intake.

#### Description of Schemes 4 and 5

65. Schemes 4 and 5 were tested with Plan E-7 modified conditions (Figure 18), which were the same as Plan E-7 (Figure 14) except for modifications to the lock filling and emptying systems. Tests were conducted with a riverflow of 16,000 cfs, which provided a maximum lift of 23.0 ft.

- a. Scheme 4. Scheme 4 provided for filling both the 1,200- and the 600-ft locks from the river channel through an intake located in the left bank of the river channel just upstream of the existing lock guide wall.
- b. Scheme 5. Scheme 5 was the same as Scheme 4 except the 600-ft lock was filled from the canal through intakes located in the upstream landward wing wall of the lock.

#### Results

66. Test results indicate that the natural surge of about 0.1 ft observed with Schemes 1-3 with the 16,000-cfs flow was not present during these tests. Model results are shown in Plates 36-40 and Photos 22-24.

- a. Scheme 4. Results shown in Plates 36-38 indicate filling either lock or both locks simultaneously from the river channel would result in small changes in water-surface elevation in the lock approach canal. The maximum change in water-surface elevations occurred during simultaneous filling of both locks with the water-surface elevations varying from about +0.2 to -0.3 at stations 1 and 2 in the lock canal (Figure 18) and about +0.2 to -0.4 at station 3 located in the river channel. Filling one or both locks had little or no effect on a tow approaching or entering the new locks in the canal or the existing lock in the river channel. A maximum velocity of about 1.5 fps would occur near the intake when both new locks were filled simultaneously (Photo 22). There was no significant tendency to pull drift from the river channel; however, ice that formed or drift that was windblown into the intake canal could be drawn into the intake structure during lock filling.
- b. Scheme 5. Data shown in Plates 39 and 40 indicate filling the 600-ft lock from the canal would increase the changes in water-surface elevations as compared to Scheme 4. When the 600-ft lock was filled, the maximum change in water-surface elevations varied from about +0.6 to -0.5 at stations 1 and 2 in the lock canal (Figure 18), and +0.1 to -0.2 at station 3 (Plate 39). If both locks were filled simultaneously, the changes in elevations at stations 1 and 3 increased slightly with a decrease at station 2 (Plates 39 and 40). It appeared that the surge from the 1,200-ft lock filling would tend to

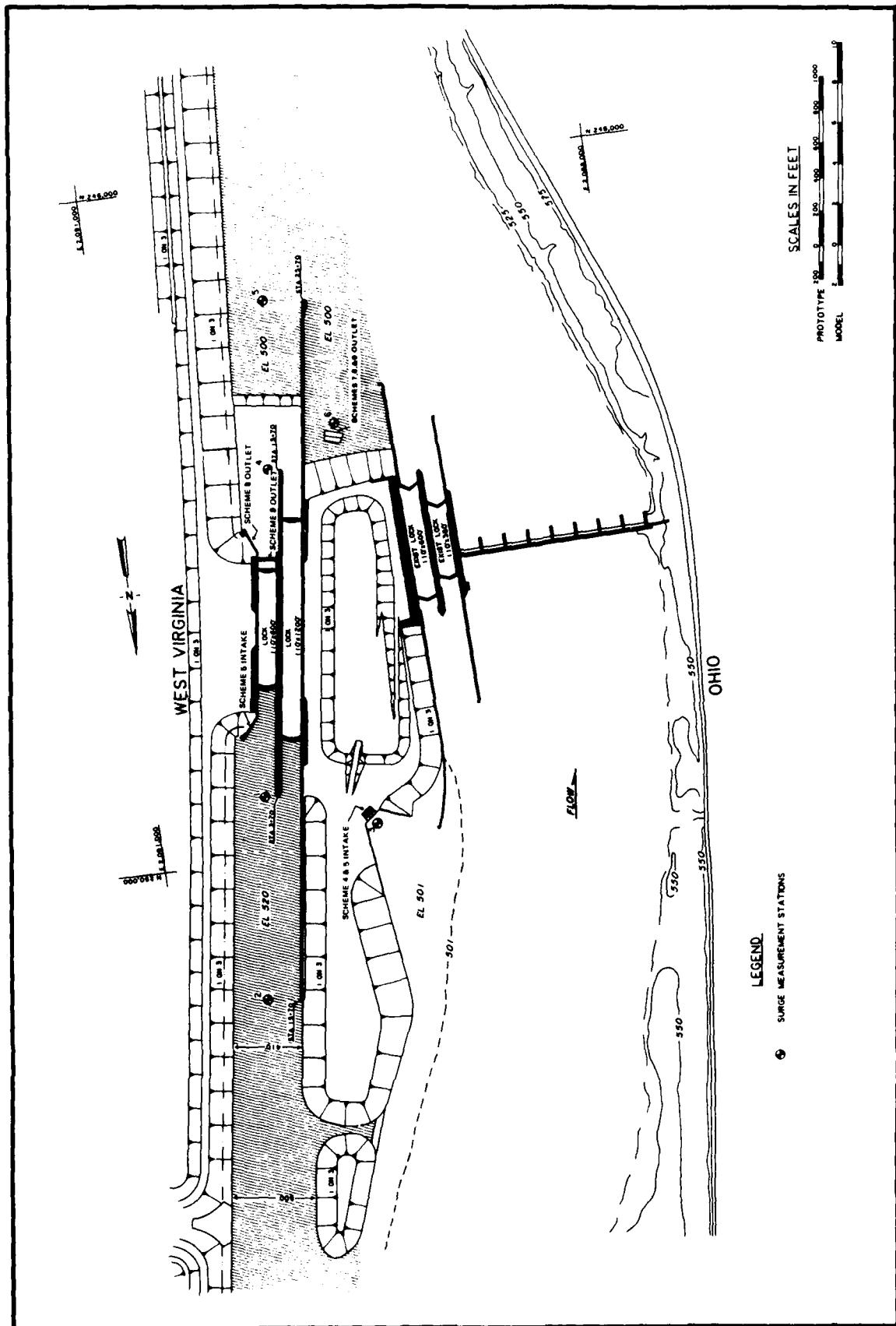


Figure 18. Plan E-7 modified

reduce the surge from the 600-ft lock filling in the vicinity of station 2 when both locks were filled simultaneously. When the 600-ft lock was filled, maximum velocities of about 1.8 fps would develop about 700 ft upstream from the end of the center lock wall and increase to about 1.9 fps in the approach to the 600-ft lock (Photo 23). These velocities were sufficient to have an adverse effect on tows in these areas (Photo 24). To avoid a collision with a lock wall during auxiliary lock fillings, a tow not underway would require a minimum distance of about 500 ft upstream from the nearest wall. Drift that collected and ice formed in the canal could be pulled into the lock approach during lock filling.

#### Description of Schemes 6-8

67. Tests were conducted with Plan E-9 modified conditions (Figure 19), which were the same as Plan E-9 (Figure 16) except that the upstream guide wall on the existing auxiliary lock was extended about 200 ft upstream to an existing guide cell.

- a. Scheme 6. Scheme 6 provided for filling both the 1,200- and 600-ft locks from the river channel through the culvert intake located in the left bank of the river channel just upstream of the existing lock guide wall as in Scheme 4.
- b. Scheme 7. Scheme 7 provided for filling the 1,200-ft lock from the river channel and the 600-ft lock from the canal. The filling intake for the main lock was located in the left bank just upstream of the existing lock guide wall, and the intake for the auxiliary lock was located in the upstream landward wing wall, as in Scheme 5.
- c. Scheme 8. Scheme 8 was the same as Scheme 7 except the intake for the auxiliary lock was located in the landward lock wall just upstream of the upper lock gate.

#### Results

68. Results shown in Plates 41-43 and Photos 25-30 indicate a slight reduction in surge and velocity measurements compared to results obtained in tests with Schemes 4 and 5, which could be attributed to the deeper lock canal. For station locations where the data were collected, see Figure 19.

- a. Scheme 6. Filling both locks simultaneously resulted in a variation in water-surface elevation at stations 1 and 2 from about +0.1 to -0.3 ft and at station 3 from about 0.0 to -0.3 ft (Plate 41) and maximum velocities of about 1.1 fps near the intake (Photo 25). These changes had no adverse effects on navigation moving in the upper lock approaches to the new or existing locks. There was no significant tendency to pull drift from the river channel; however, ice that forms or drift windblown into the approach to the intake could be drawn into the intake structure the same as with Scheme 4. Any adverse

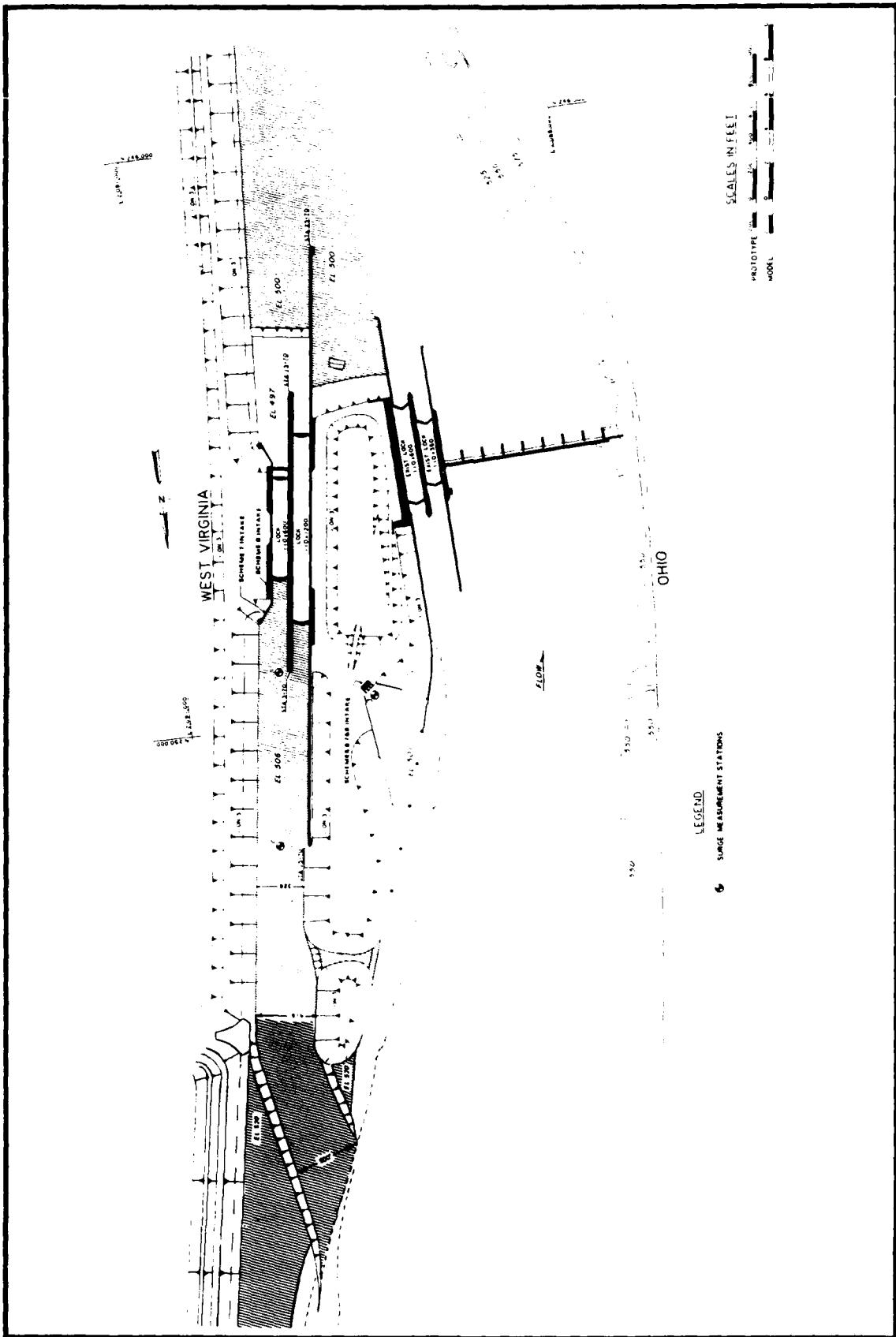


Figure 19. Plan E-9 modified

effects resulting from lock filling with this scheme would be reduced when filling one lock.

- b. Scheme 7. Filling the auxiliary lock produced the greater effects on navigation and resulted in a variation in water-surface elevation at stations 1 and 2 from about +0.2 to -0.4 ft and at station 3 from about +0.1 to -0.2 ft (Plate 42). Maximum velocities of about 1.1 fps would develop near the upstream end of both the guide walls to the new locks (Photo 26). These velocities were sufficient to have an adverse effect on tows in these areas (Photo 27). To avoid a collision with a lock wall during the filling of the auxiliary lock, a tow not underway would require a minimum distance of about 400 ft upstream of the nearest wall. Drift that collected and ice that formed in the canal could be pulled into the lock approach during lock filling.
- c. Scheme 8. When the auxiliary lock was filled, surges were increased somewhat, particularly at station 1 compared to results obtained in tests with Scheme 7. Water-surface elevations varied from about +0.4 to -0.5 ft at station 1, +0.2 to -0.4 ft at station 2, and +0.1 to -0.2 ft at station 3 (Plate 43). Maximum velocities of about 1.1 and 1.0 fps would develop near the upstream end of the lock guide walls (Photo 28). These velocities were sufficient to have an adverse effect on tows in these areas (Photos 29 and 30). To avoid a collision with a lock wall during the filling of the auxiliary lock, a tow not underway would require a minimum distance of about 400 ft upstream of the nearest wall (same as Scheme 7).

#### Description of Scheme 9

69. Scheme 9 was tested with Plan E-10 modified conditions and was the same as Plan E-10 except the existing upstream guard wall was removed. Water for filling both the new locks was supplied from the river through an open channel located in the left bank just upstream of the existing lock guide wall. The intakes for the main lock were located in a tower in the channel about 200 ft riverward of the riverside guide wall and in the riverward face of the riverside guide wall. The intake for the auxiliary lock was located in the same wall about 140 ft upstream from the main lock intake (Figure 20).

#### Results

70. Conditions created in the upstream approach to the new locks during tests were very similar to results obtained during tests with Scheme 6. Filling the main lock or both locks simultaneously through the channel from the river resulted in a variation in water-surface elevation at stations 1 and 2 from about +0.1 to -0.3 ft (Plates 44 and 45) and about +0.1 to -0.15 ft when filling the auxiliary lock (Plate 46). The water-surface elevation at station 3, when filling the auxiliary lock or main lock or both locks

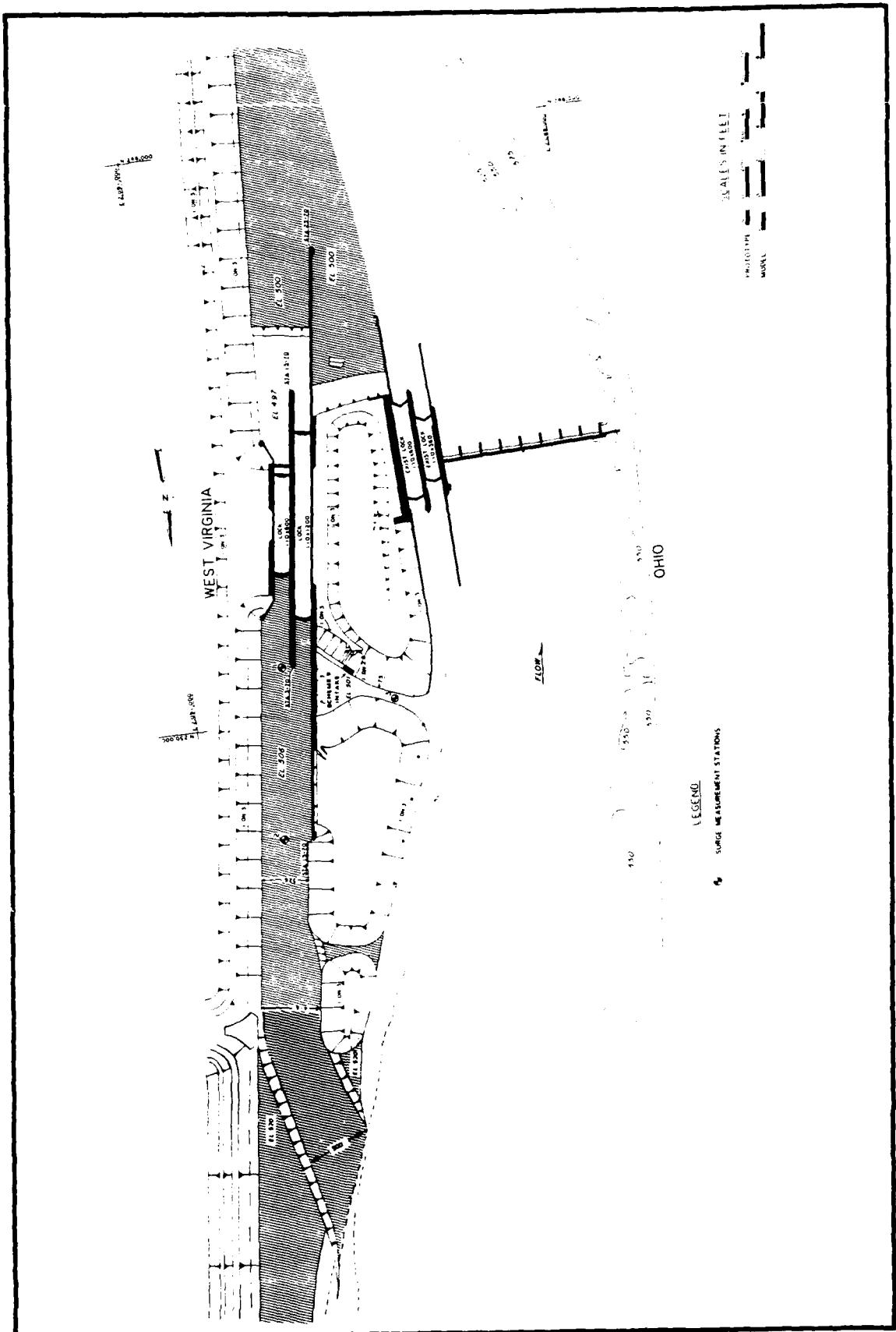


Figure 20. Plan E-10 (upper guard wall in place on the existing lock)

simultaneously, varied from about +0.1 to -0.3 ft (Plate 46), -0.4 ft (Plate 44), and -0.6 ft (Plate 45). These test conditions had little or no effect on a tow approaching or entering the new locks in the canal. When both locks were filled simultaneously, a maximum velocity of about 3.7 fps occurred in the channel from the river to the intake structure (Photo 31); and when filling only the 1,200-ft lock, the maximum velocity was reduced to about 2.2 fps (Photo 32). These velocities were sufficient to adversely affect a tow approaching the existing locks at a slow rate of speed near the upstream end of the existing guide wall (Photo 33). However, a tow moving a short distance riverward of the guide wall could overcome the effects of these currents; and as the river discharge was increased, the effects of these currents on a tow were reduced considerably.

#### Lock Emptying Tests

##### Procedure

71. Tests were conducted to determine the effects of lock emptying on navigation conditions in the downstream approach to the new locks with different types and locations of emptying structures, lock arrangements, and channel configurations. Tests were conducted with no flow through the dam and maximum lift at the locks of 23 ft (normal upper and minimum lower pool).

##### Description of Schemes 1-5

72. Conditions tested were the same as Plan E-3 (Figure 10) with the following schemes:

- a. Scheme 1. Four emptying outlets (two for each lock) were located on each side of the common guide wall near its lower end and near the lower end of each of the wing walls. The outlets were of the pan type with the tops flush with the bed of the channel.
- b. Scheme 2. This scheme was the same as Scheme 1 except that the outlets at the lower ends of the wing walls were moved to about the midpoint of the common guide wall on each side.
- c. Scheme 3. This scheme was the same as Scheme 2 except that the outlets at the midpoint of the common guide wall were relocated on the left bank of the bypass canal downstream of the wing wall of the landside lock.
- d. Scheme 4. The wing wall on the riverside lock was extended 300 ft and the guide wall on the existing landside lock was removed. The number of outlets was reduced to two, one for each lock, and were of the conventional type used on other Ohio

River locks. The outlets were located in the left bank in the lower approach to the existing landside lock.

- e. Scheme 5. This scheme was the same as Scheme 4 except that the lower portions of the existing locks were removed and the outlets located in an area of the existing main lock chamber.

### Results

73. The results of tests, shown in Table 3, indicated the following:

- a. Schemes 1 and 2. The difference in the effects of lock emptying between Schemes 1 and 2 was small. The maximum surge measured with one lock emptying was about 0.6 ft in the approach to that lock and about 0.2-0.3 ft in the other lock approach. When both locks were emptied simultaneously, the surge varied from about 0.7 ft in the approach to the riverside lock and up to about 1.0 ft in the approach to the landside lock. Maximum velocities in the lock approaches with both locks emptying at the same time were about 2.3 fps in the riverside lock and about 2.5 in the landside lock (Photos 34 and 35).
- b. Scheme 3. Maximum surge measured while emptying the landside lock with this scheme was about 0.6 ft in the approach to that lock and about 0.2 ft in the approach to the riverside lock. During emptying of the riverside lock, the maximum surge was about 0.2 ft in the approach to that lock and 0.4 ft in the approach to the landside lock. When both locks were emptied at the same time, the maximum surges in the approaches were about 1.0 ft for the landside lock and about 0.5 ft for the riverside lock. Velocities in the approach to the landside lock were considerably higher than with Schemes 1 and 2 and somewhat less in the approach to the riverside lock.
- c. Schemes 4 and 5. There was little difference between the surges obtained in the lock approaches during lock emptying with Schemes 4 and 5. The maximum surges while emptying either the landside or riverside lock were about 0.3 ft in the landside lock approach and about 0.4 ft in the riverside lock approach. When both locks were emptied at the same time, the maximum surge measured was about 0.6 ft or less in the approaches to both locks.

74. The head on the lower lock gates at the end of the lock emptying operation was not more than about 0.1 ft with any of the schemes tested. Navigation conditions, particularly for upbound tows approaching the lower guide wall, would be adversely affected by the surge and currents developed during lock emptying with Schemes 1, 2, and 3. No serious navigation difficulties were indicated with either Scheme 4 or 5.

### Description of Scheme 6

75. Scheme 6 was tested with two different plans; however, the outlet was the same for both plans and was located at the lower end of the island

between the bypass canal and the river. In Plan E-4 (Figure 11), the guide wall was on the landside of the lock with a long wing wall on the riverside. In Plan E-5 (Figure 12), the guide wall was on the riverside of the lock with a short wing wall on the landside.

#### Results

76. Current patterns created during lock emptying with Plan E-4 are shown in Photos 36 and 37. These results indicate that there would be no appreciable currents in the lower approach to the new lock during lock emptying. A clockwise eddy formed downstream of the wing wall that extended into the approach to the existing lock. Maximum velocities in the eddy were as much as 2.1 fps. Current patterns created during lock emptying with Plan E-5 (Photos 38-40) indicate the same general trends as with Plan E-4. Maximum velocities in the eddy were about 2.1 fps and extended into the lower approach to the existing lock, about the same as with Plan E-4. There was no indication of any currents in the approach to the new lock. Lock emptying with Plan E-4 or E-5 had no adverse effect on navigation conditions in the lower approach to the new lock and very little effect on tows approaching the existing locks, even with no flow through the dam.

#### Description of Schemes 7-9

77. Schemes 7-9 were tested with Plan E-7 modified conditions (Figure 18), which were the same as Plan E-7 except for the filling and emptying structures. Tests were conducted with these schemes to determine navigation conditions in the approaches to both the new and existing locks. Outlet locations for the different emptying schemes are shown in Figure 18 and described as follows:

- a. Scheme 7. The emptying outlet for the two locks was located at the lower end of the island between the bypass canal and the river.
- b. Scheme 8. The outlet for the main lock was the same as in Scheme 7 with the auxiliary lock outlet located in the downstream landward wing wall.
- c. Scheme 9. The outlet for the main lock was the same as in Schemes 7 and 8 with the auxiliary lock outlet located just downstream of the auxiliary lock miter gate.

#### Results

78. Results shown in Plates 47-53 and Photos 41-46 indicated the following:

- a. Scheme 7. Changes in water-surface elevation in the approach

to the new locks (stations 4 and 5) varied from about +0.3 to +0.5 ft during lock emptying. There were no significant differences between emptying the locks separately or simultaneously. At station 6, the changes in elevation varied from about +0.2 to +0.4 ft. Due to the relatively flat shape of the leading edge of the surge wave and to the slow fall in elevation after the initial surge (Plates 47-49), there were no major effects on navigation in the approach to the new locks. However, navigation in the downstream approach to the existing locks could be affected adversely during simultaneous lock emptying, particularly if the tow was in the vicinity of the downstream end of the existing landward guide wall. There was a strong tendency for the tow to be rotated in a clockwise direction or moved riverward of the lock approach depending on the location of the tow at the time the locks were emptying. Surface current patterns that developed in the lock approach with both locks emptying simultaneously are shown in Photo 41, and the resulting current alignment and velocities in Photo 42. The current pattern and maximum velocities were very similar when only the 1,200-ft lock was emptied; however, the duration was somewhat shorter. The reduction in duration of maximum velocities with the single lock emptying would reduce somewhat the adverse effects on tows moving in the approach to the existing locks. It was observed that the tendency for the tows to be moved from the lock approach as they neared the end of the guide wall was reduced considerably for both these conditions with flow through the gated spillway.

- b. Scheme 8. There were no significant differences in water-surface elevations in the downstream approach to the new locks (stations 4 and 5) with emptying one lock or both locks simultaneously. The elevations varied from about +0.4 to -0.2 ft or less. At station 6 the elevations increased about 0.1 ft with the 600-ft lock emptying and about 0.4 ft when emptying both locks simultaneously (Plates 50 and 51). Surface currents developed during emptying of the auxiliary lock are shown in Photo 43. Current alignment and velocities are shown in Photo 44. These current velocities could adversely affect a tow in the approach to the new lock, particularly if the tow was located near the end of the center lock wall where the current tended to move a tow downstream about 200 ft when the lock was emptied. The adverse effect was reduced considerably when a tow was located about 100 ft off the riverward guard wall with its head near the end or within a short distance downstream of the wall as the lock was emptied. At this location or further downstream, a tow should be able to maintain control without any major difficulties during lock emptying. Once the initial surge passed the end of the guard wall, the effects on navigation were reduced considerably.
- c. Scheme 9. The shape of the initial surge waves obtained during lock emptying with Scheme 9 (Plates 52 and 53) was generally the same as in Scheme 8; however, the variation in water-surface elevation was increased somewhat, and the time required

for conditions to stabilize in the lock approach (stations 4 and 5) was much shorter. The surface current patterns developed during emptying the auxiliary lock (Photo 45) and during emptying both locks simultaneously were about the same as in Scheme 8. Maximum velocities of 1.6 fps obtained in the approach when emptying the auxiliary lock (Photo 46) were slightly greater than with Scheme 8; however, the effects on the tow in the approach to the new locks were about the same. One noticeable difference with this scheme was that if a tow was near the new auxiliary lock entrance during lock emptying, there was a tendency for the tow to be moved toward the center lock wall, then downstream. In Scheme 8, the tow would tend to be moved in a downstream direction only. Navigation conditions in the approach to the existing locks with Schemes 8 and 9 were about the same as with Scheme 7 when emptying the 1,200-ft lock. Observations of tests indicated that with Schemes 8 and 9, conditions would be improved in the approach to the existing locks with flows through the gated spillway.

#### Sediment and Drift Tests

##### Upstream bypass canal

79. Description. Tests were conducted to obtain a qualitative indication of the movement of drift and sediment into the canal upstream of the new locks with Plan E-2 (Figure 9). Drift was simulated with floats submerged 3 ft and sediment was indicated by the movement of a colored solution having a specific gravity slightly greater than water.

80. Results. Tests indicated that about 60 percent of the drift moving within 350 ft of the left bank would enter the canal with the 75,000-cfs flow and about 43 percent with the 466,000-cfs flow. Most of the drift entering the canal would be moved riverward through the channel across the island. Some of the drift would tend to remain in the canal and be trapped in the eddy along the left bank. There would be little movement of drift toward the locks except as affected by wind or traffic.

81. The results of sediment tests indicated that there would be little or no tendency for sediment moving as bed load to enter the canal with the 75,000-, 217,000-, and 466,000-cfs flows. Some deposition could occur in the canal from material carried in suspension and would tend to be concentrated along the left bank in the eddy area.

##### Lower lock approach

82. Description. Sediment tests were conducted with a discharge of 217,000 cfs (open river conditions) to obtain a qualitative indication of the

movement of sediment into the lower lock approach with existing conditions and Plan E-5 (Figure 12). A colored solution having a specific gravity slightly greater than water and a plastic granular material having a specific gravity of about 1.28 were used to indicate sediment movement. Test results were based on an average of several different runs using the same quantity of dye and plastic granular material for each run introduced at the same location in the model.

83. Results. The size, shape, and location of the area where deposition could occur from material carried in suspension and as bed load are indicated in Plate 54. The results indicated that the area in the lower approach where sedimentation could occur would be about 47 percent greater with Plan E-5 than that with existing conditions. The material moving along the bed (bed load) would be deposited generally in the same area as with existing conditions. However, due to the slow eddy currents with Plan E-5, only about half as much of the material was deposited as with existing conditions. These results generally indicate that deposition in the lower lock approach with Plan E-5 would not be substantially different from what is occurring at the existing locks and could be less. Deposition in these areas could vary somewhat depending on the amount and type of material carried in suspension and the effects of barge traffic in the area.

#### Intake structures

84. Description. Preliminary tests were conducted to determine the movement of sediments, drift, and ice into the intake structures during lock filling with Plan E-9 modified (Figure 19), Schemes 6-8; and Plan E-10 modified (Figure 20), Scheme 9. Dye, confetti, and wooden floats submerged 9 ft (to determine current velocities) were used to simulate the movement of fine sediments, drifts, and ice moving in the river channel.

85. Results. Based on observation of the movement of dye, confetti, and floats and measurement of velocities near the intakes, most of the sediment collected in the approach to the intakes with Schemes 6-8 would be that carried in suspension. Most problems at the intakes would be caused by debris, either windblown or moved in the canal by downbound tows, or ice formed in the approach to the intake structures. Due to the concentration of flow at the entrance to the filling channel with Scheme 9, fine sediments, drift, or ice located near the entrance could be moved into the channel and to the intake structures during lock filling when the river discharges were low

(Photo 47). However, as the river discharges were increased, the tendency for sediments, drift, and ice to enter the filling channel from the river was decreased considerably (Photo 48). Some type of barrier could be constructed at the entrance to the filling channel to prevent drift and ice from moving from the river into the filling channel (Photo 49). However, it should be noted that some of the larger pieces of ice or drift could approach the barrier with velocities as great as 2.5 fps (Photo 50).

## PART VI: ALTERNATE SITE

86. In connection with the improvement of navigation conditions at the Gallipolis Locks and Dam, a complete replacement structure was also considered. The site selected for the replacement structure was in the vicinity of mile 282.4, about 3 miles downstream of the existing dam. The purposes of the model study of the structure at this site were to determine navigation conditions that could be expected with the proposed design, develop modifications required to improve navigation conditions, and provide data that could be compared with results from modifications at the existing site.

### Base Test

#### Description

87. The base test was conducted with existing conditions before the installation of the replacement structure. The purpose of this test was to obtain data that could be used to determine the effects of the proposed structure on flow conditions and water-surface elevations. The reach of the river reproduced and channel configurations are shown in Figure 3.

#### Results

88. Water-surface elevations in the reach before the installation of the proposed downstream replacement structure are shown in Table 4. These results indicate water-surface slopes in the reach with the higher flows varying from about 0.4 ft per mile to about 0.5 ft per mile.

89. Current directions and velocities shown in Plates 55-58 indicate the alignment of the currents was generally parallel with the bank lines and velocities were generally high. Velocities along the right bank in the vicinity of the proposed location for the replacement locks varied from about 3.8 fps with the 75,000-cfs flow to about 8.6 fps with the 465,000-cfs flow. Some velocities with the higher flows exceeded 9.0 fps away from the right bank line.

### Plan A-1

#### Description

90. Plan A-1 involved the installation of the replacement locks and dam

structure as originally proposed. The essential features of this plan, shown in Figures 21 and 22, were as follows:

- a. Two parallel locks with clear chamber dimensions of 1,200 by 110 ft were located along the right bank. The riverside lock had a 961-ft-long upper guard wall with 17 ports 28 ft wide with top of ports at el 523.0 and a 1,110-ft-long solid lower guard wall. The landside lock had a 492-ft-long upper guide wall with seven 18-ft-wide ports with top at el 513.0 and a 510-ft-long lower guide wall. Tops of lock walls were at el 557.0.
- b. A nonnavigable type dam with eight 110-ft-wide gate bays and nine 15-ft-wide piers extending from the riverside lock to the left bank. The gate sills were at el 502.0.
- c. An overflow weir with crest at el 540.0 extending from the left abutment of the gated dam to high ground on the left overbank.
- d. Esplanade and fill to el 557.0 between the landside lock and right overbank.
- e. Excavation along the right bank in the upper approach to the landside lock to a bottom el 520.0 and along the left bank extending about 4,000 ft upstream of the dam to a bottom el 520.0 and about 9,500 ft downstream to bottom el 507.0.

#### Results

91. Water-surface elevations shown in Table 5 indicate that installation of the locks and dam increased stages upstream of the dam some 0.3 to 0.5 ft with the 232,000- and 465,000-cfs flows and about 0.8 to 1.0 ft with the 500,000-cfs flow. With uncontrolled riverflows the drop in water-surface elevation across the dam (Gages 5-6) varied from about 0.3 ft with the 232,000-cfs flow to about 0.5 ft with the 500,000-cfs flow.

92. Current directions and velocities obtained with Plan A-1 are shown in Plates 59 and 60. These results indicate that the alignment of the currents approaching the locks were generally parallel to the right bank except as affected by the clockwise eddy that formed along the bank in the lock approaches. The velocity of currents along the right bank upstream of the locks was generally less than that obtained in the base tests. Most of the area between the upper guard wall of the riverside lock and the right bank was occupied by the eddy. Velocities approaching the upper guard wall from along the right bank were as much as 5.8 fps with the 232,000-cfs flow and about 7.5 fps with the 465,000-cfs flow. Currents downstream of the dam moved from the riverside of the lower guard wall (riverside lock) toward the right bank about 3,000 ft downstream, creating a clockwise eddy along the bank in

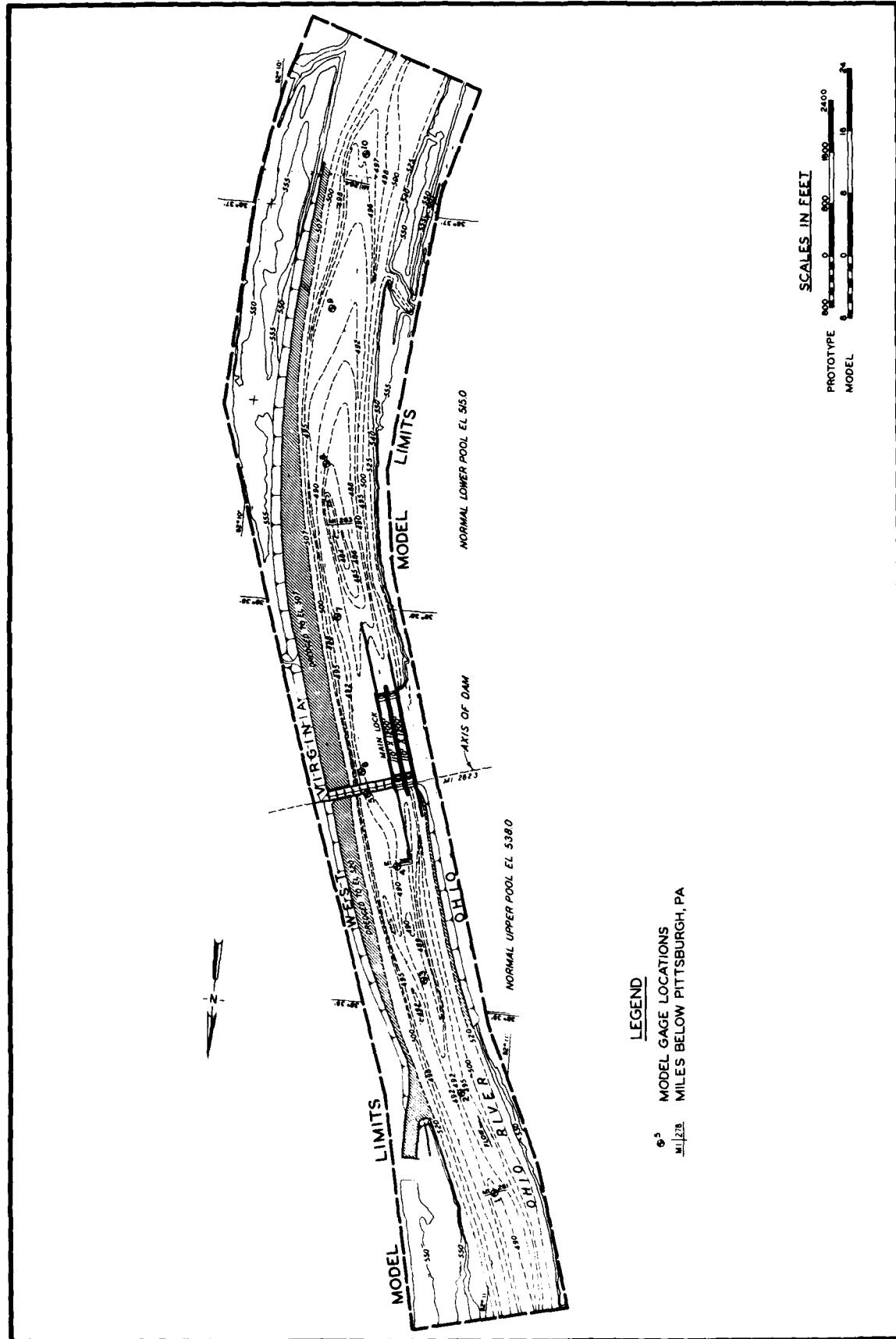


Figure 21. Plan A-1

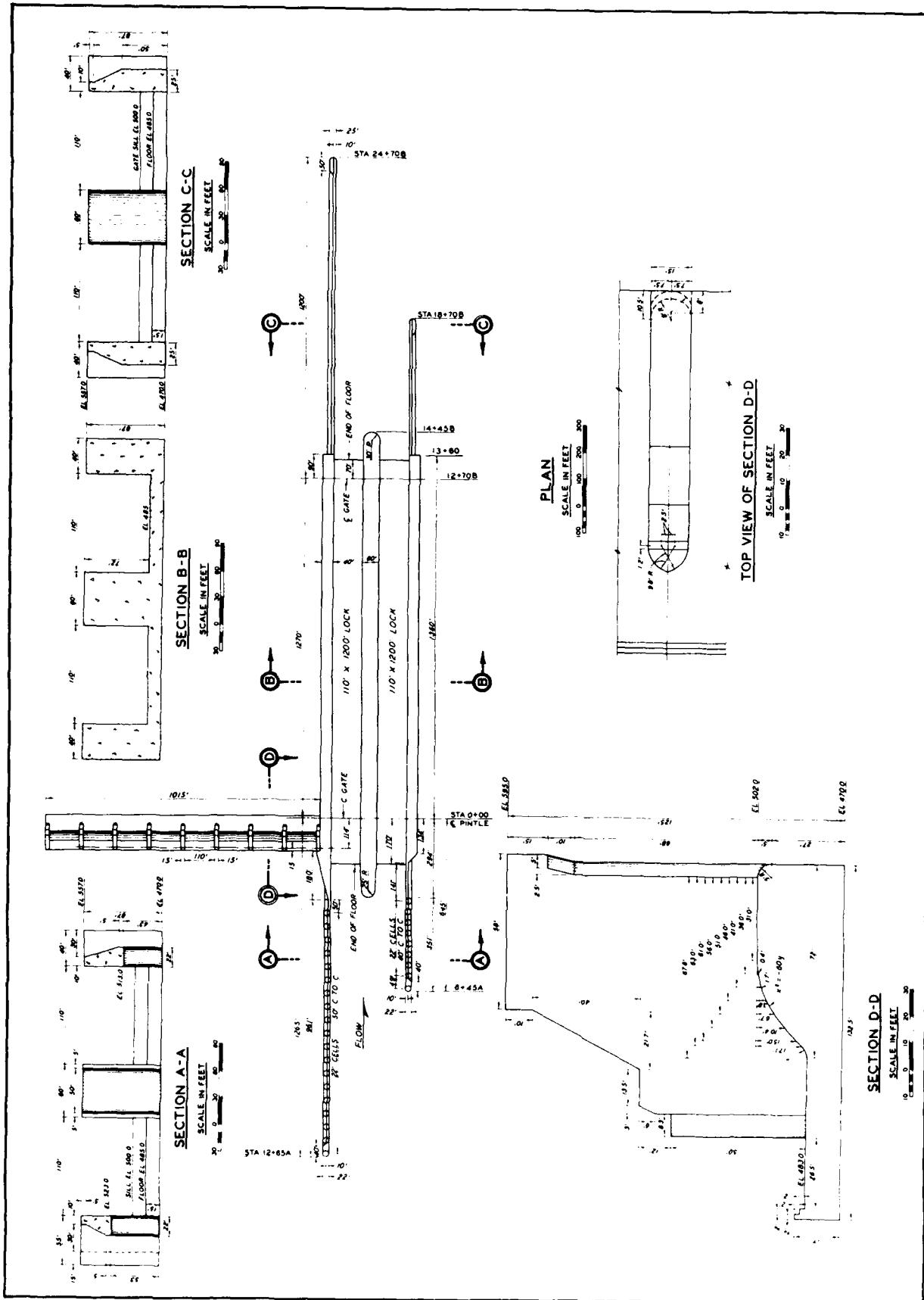


Figure 22. Plan A-1, general plans and sections of proposed replacement structure

the lower approach to the locks. Velocities of currents moving toward the right bank were as much as 5.4 fps with the 232,000-cfs flow and 4.9 fps with the 465,000-cfs flow. Velocities in the eddy in the lower lock approach varied from less than 1.0 to 4.4 fps.

93. Navigation conditions in the upstream approach to the locks would be affected adversely by the bend in the right bank immediately upstream of the locks, the crosscurrents moving riverward from along the right bank just upstream of the locks, and the limited width of the approach channel landward of the riverside guard wall. No serious difficulties were indicated for up-bound tows approaching the locks. However, because of the maneuvering required to enter the locks, two-way traffic would not be practical in the lower or upper approach to the locks. No difficulties were indicated for tows leaving the locks in either direction.

#### Plan A-2

##### Description

94. Plan A-2 was designed to improve navigation conditions, particularly in the upper lock approach, and to provide for two-way traffic in the approaches insofar as conditions would permit. This plan, shown in Figure 23, involved the following modifications developed during preliminary tests:

- a. The ported section of the upper guard wall on the riverside lock was extended to 1,865 ft upstream of the upper lock gate pintles. The guide wall on the landside lock was removed and a cell type guard wall was placed on the end of the intermediate wall extending 894 ft upstream. The guard wall for the landside lock contained 13 ports, 18 ft wide, with the top of ports at el 523.0.
- b. The lower guard and guide walls were replaced with 115-ft-long wing walls angled 15 deg from each lock approach with top el 557.0. The riverside wing wall was extended by two 25-ft-diam cells with a top el 557.0 spaced 75 ft apart in line with the wall beginning 75 ft downstream from the end of the wall. The spacing between the cells and the wall were rock-filled to el 520.
- c. The intermediate wall was extended downstream 1,115 ft to form a common lower guide wall for both locks.
- d. Excavation along the right bank upstream of the locks was increased to 360 ft landward of the riverward lock guard wall and extended about 4,200 ft upstream of the dam parallel to the riverward guard wall. The excavation was limited by the Ohio

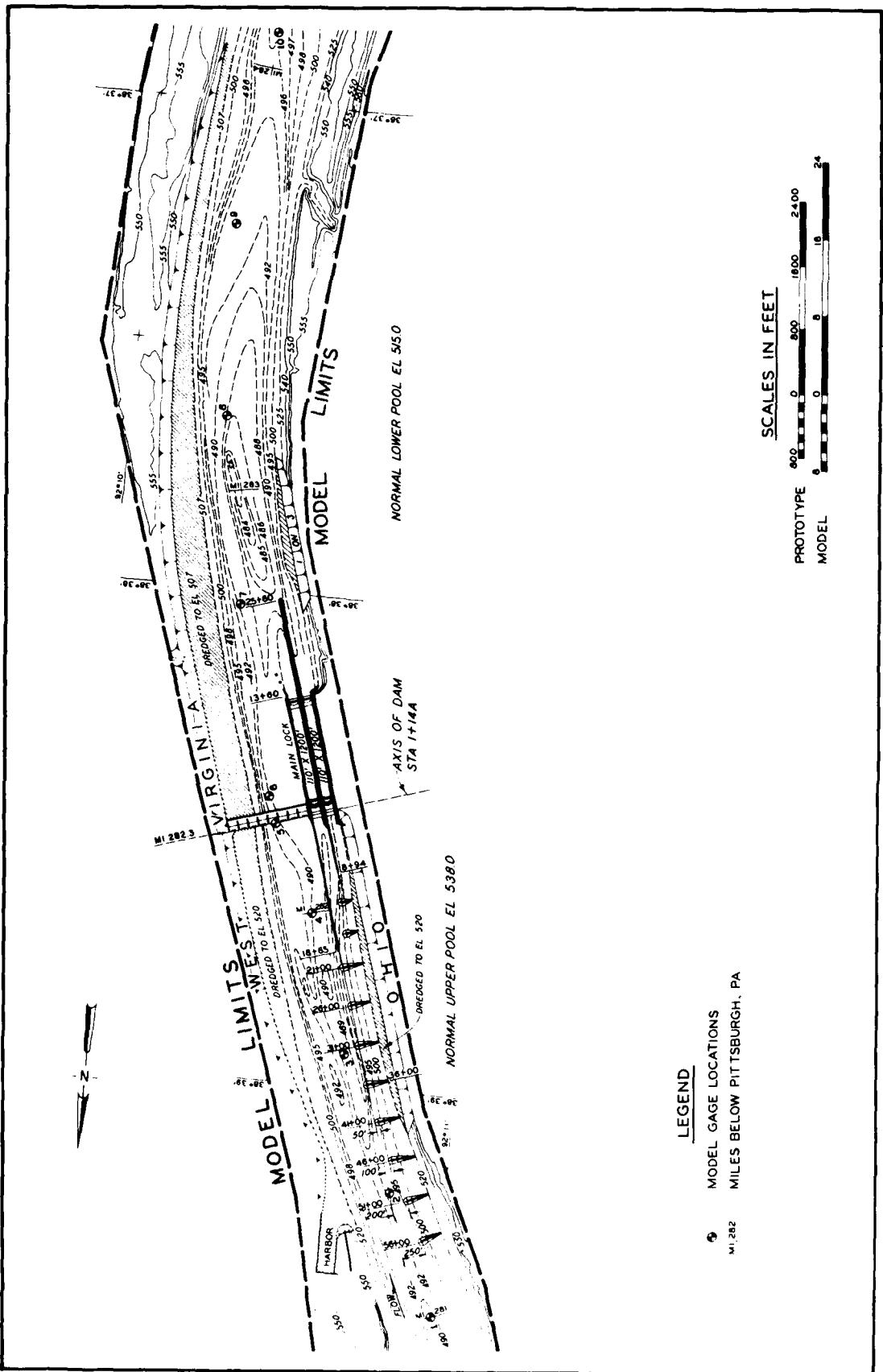


Figure 23. Plan A-2

Highway No. 7 along the bank. The scallop portion of the right bank downstream of the locks was excavated to a bottom el 500.0 beginning near the downstream end of the common guide wall and extending about 2,000 ft downstream with a 1V on 3H side slope.

- e. Ten submerged dikes, top el 520.0, were located in the upstream approach to the locks. Eight dikes 250 ft long, spaced 500 ft apart, were located between sta 21+00A and 56+00A, and two dikes 130 ft long, spaced 200 ft apart, were located downstream of sta 21+00A.

#### Results

95. Results shown in Table 6 indicate some lowering of the water-surface elevations upstream of the dam with little change downstream compared with Plan A-1. With uncontrolled riverflows there was no appreciable difference in the drop in water-surface elevation across the dam, which ranged from about 0.3 to 0.5 ft. The drop in water-surface elevation from near the end of the upper guard wall of the riverside lock downstream to the end of the common lower guide wall (Gages 4-7) varied from 0.7 ft with the 232,000-cfs flow to about 1.0 ft with the 500,000-cfs flow. The water-surface elevations at Gage 4 were affected to some extent by its location near the end of the upper guard wall.

96. Velocities in the upper lock approach with this plan were considerably less than with Plan A-1 (Plates 61-63). The eddy in the upper approach to the locks was practically eliminated with the 75,000-cfs flow and reduced significantly with the higher flows. Most of the currents along the excavated portion moved into the lock approach with little indication of crosscurrents. Maximum velocities near and just upstream of the end of the upper guard wall of the riverside lock varied from about 3.3 fps with the 232,000-cfs flow to about 5.1 fps with the 465,000-cfs flow. Velocities were generally higher farther upstream. In the downstream lock approaches, a large eddy formed along the right bank just downstream of the common guide wall. There was also a tendency for a small eddy to develop along the riverside of the common guide wall. The velocity of the eddy currents was generally low and less than 1.0 fps.

95. Navigation conditions for downbound tows approaching either lock were improved considerably compared with Plan A-1. Tows could approach the riverward lock from a considerable distance off the right bank without major difficulty. Tows using the landward lock had to approach from close along the right bank and maintain proper alignment, particularly during the higher

flows. However, due to the channel alignment near the upstream limits of the right bank excavation and the limited distances in the approach, downbound tows would have to maintain sufficient steerage to negotiate the right turn into the lock approach and have the tow properly aligned before approaching the guard walls. There were no navigation difficulties indicated in the downstream approach to either lock. Because of the separation provided by the common lower guide wall, tows entering or leaving one lock would not interfere with tows entering or leaving the other lock. It was noted that with the cells and fill at the end of the wing wall removed, there would be a tendency for upbound tows using the riverside lock to be moved riverward of the guide wall as they approached the lock.

#### Plan A-3

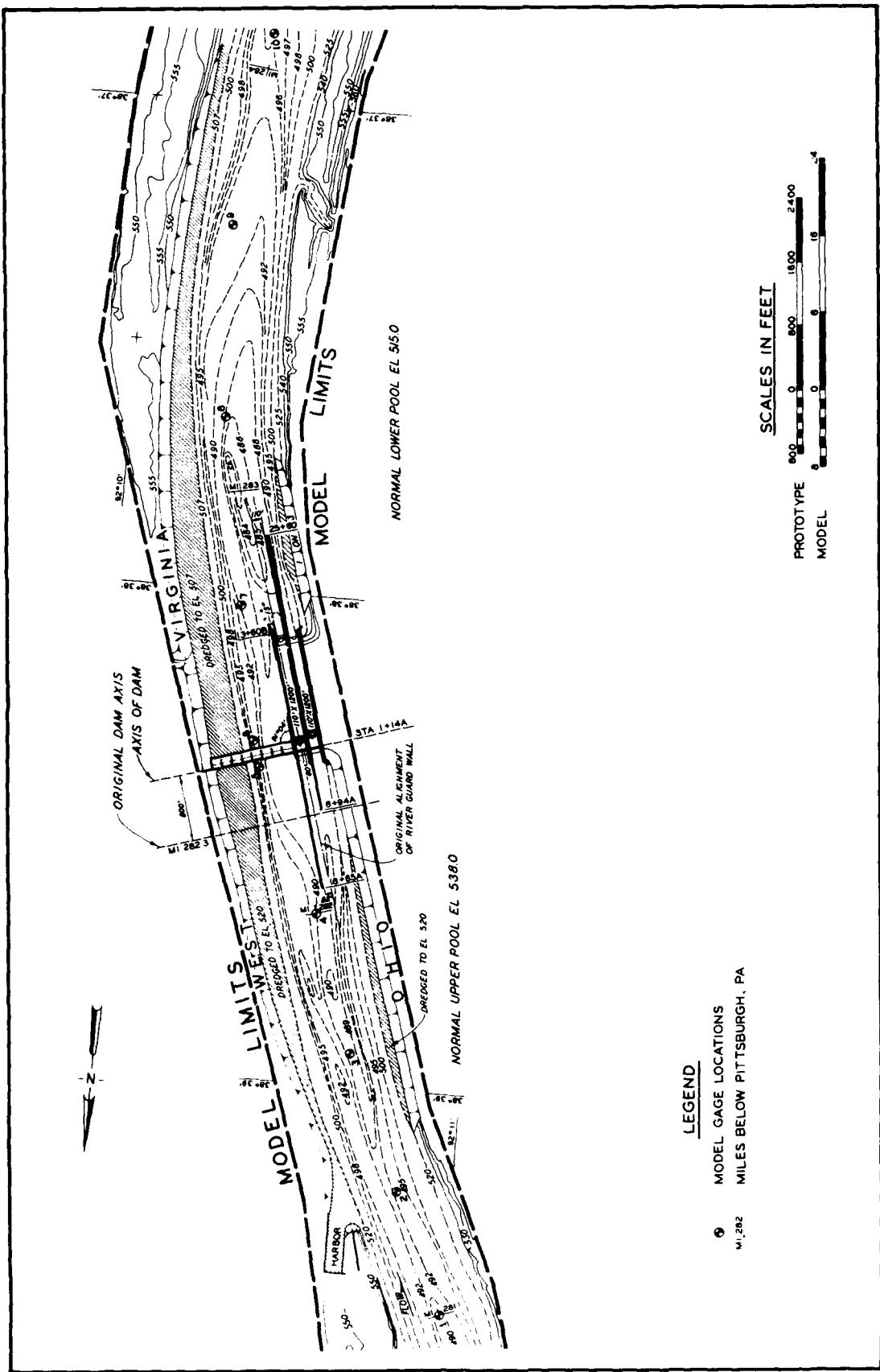
##### Description

98. Plan A-3 was the same as Plan A-2 except for the following (Figure 24):

- a. The locks and dam were moved 800 ft downstream along the center line of the lock.
- b. The locks and lock walls were rotated riverward 50 ft at the axis of the dam with the downstream end of the lower guide wall used as a pivot. This placed the upper portion of the lock walls at an angle of 88 deg 56 min with the axis of the dam and moved the end of the upstream riverward guard wall 90 ft riverward.
- c. The submerged dikes along the right bank in the upper lock approach were removed.

##### Results

99. Water-surface elevations shown in Table 7 indicate some increase in water-surface elevations upstream of the dam ranging from about 0.1 to 0.5 ft with the 465,000- and 500,000-cfs flows compared to results obtained with Plan A-2. The increase was somewhat greater with the 465,000-cfs flow than with the higher flow. It should be noted that Gage 4 was located upstream of the upper guard wall with this plan and downstream of the end of the guard wall with Plan A-2, which would account for the higher elevation at that gage. Also, Gages 5 and 6 were moved 800 ft downstream in the same relative position to the dam as in Plan A-2. There was little change in water-surface elevations downstream of the dam. The drop in water level across the dam with



uncontrolled riverflows varied from 0.4 ft with the 465,000-cfs flow to 0.6 ft with the 500,000-cfs flow.

100. Current directions and velocities shown in Plates 64-66 indicate that currents approaching the locks were generally straight and parallel to the right bank except for the eddy that formed in the approach to the landside lock. The size of the eddy was larger than the eddy obtained with Plan A-2. Velocities approaching the riverside guard wall were also higher, ranging up to a maximum of about 7.7 fps with the 465,000-cfs flow. Current directions and velocities in the lower lock approach were about the same as with Plan A-2 except for some changes in the eddies in the lock approaches.

101. Navigation conditions for downbound tows approaching the riverside lock were improved compared with Plan A-2 because of the increase in the straight-line distance approaching the lock. Due to the high-velocity currents during the higher flows, downbound tows would tend to approach the guard wall at relatively high speed, and some flanking might be required to reduce their forward motion. No serious difficulties were indicated for downbound tows approaching the landside lock. However, because of the large eddy forming along the right bank, considerable maneuvering might be required if the tow is not properly aligned before approaching the guard wall. No navigation difficulties were indicated in the downstream lock approaches.

#### Plan A-4

##### Description

102. Plan A-4 was the same as Plan A-3 except for the following (Figure 25):

- a. The locks and lock walls were rotated landward 50 ft at the axis of the dam pivoting at the end of the lower guide wall, placing the alignment of the locks normal to the center line of the dam as in Plan A-2.
- b. The tops of ports in the upper guard wall of the riverside lock were raised to el 528.0.
- c. The length of the guard wall for the landside lock was extended upstream to sta 10+10. The wall contained sixteen 18-ft-wide ports with top el 523.0.
- d. Excavation along the left bank upstream of the dam was reduced and tied into the existing bank line about 2,100 ft upstream of the dam.

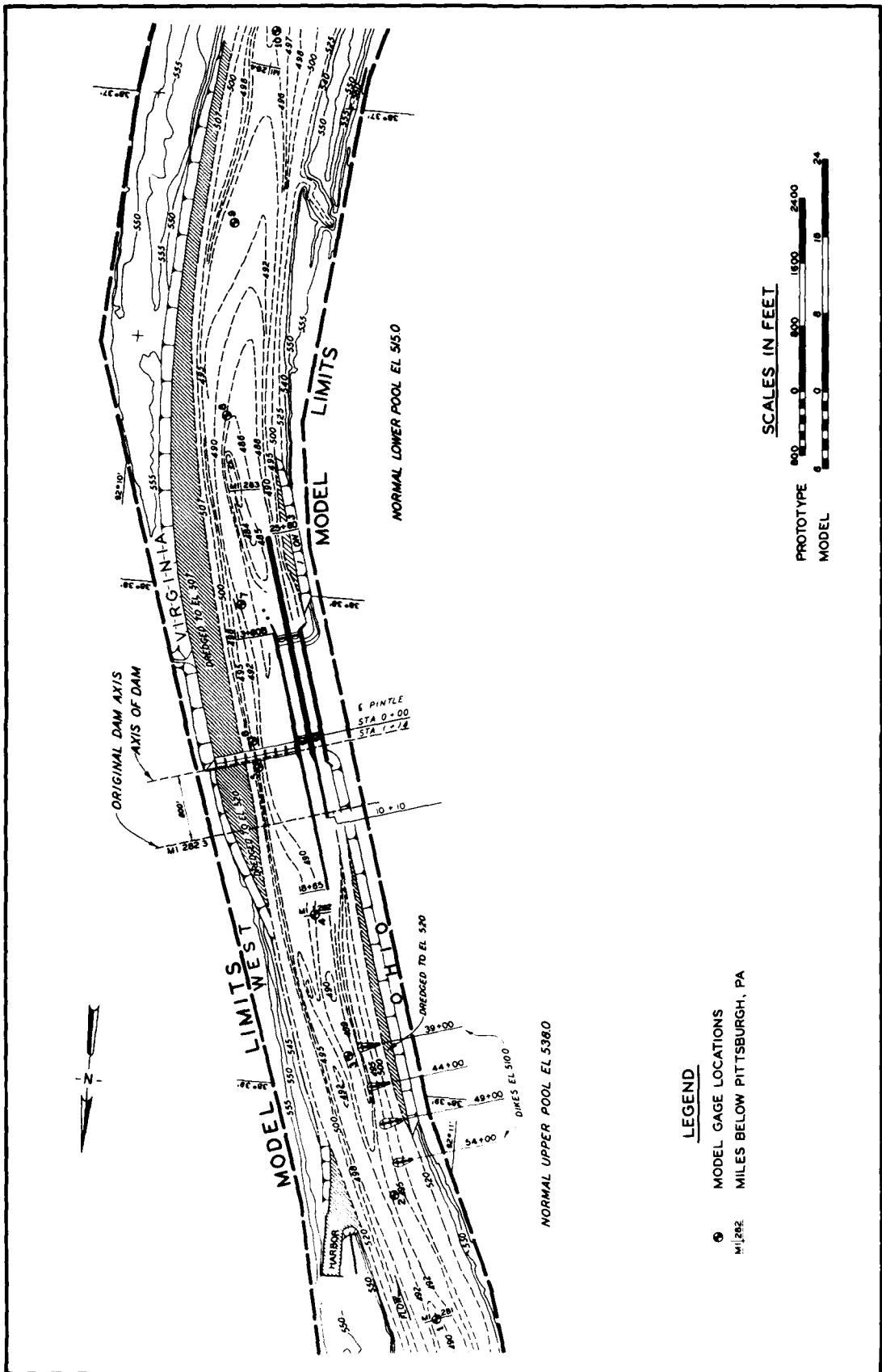


Figure 25. Plan A-4

e. Four submerged dikes were placed normal to the upper approach channel between sta 39+00 and 54+00. The dikes were about 250 ft long, each with a top el 510.0, and spaced about 500 ft apart.

### Results

103. Water-surface elevations with Plan A-4 (Table 8) were about 0.1 to 0.3 ft lower upstream of the dam with little change downstream of the dam compared to results obtained with Plan A-3. Water-surface elevations upstream of the structures were generally about 0.6 ft higher than without the proposed structures (base tests).

104. The alignment of the currents approaching the locks was improved compared with Plan A-3, with some reduction in the velocities. The size of the eddy in the approach to the landside lock was reduced considerably (Plates 67-69). There was an increase in the amount of flow moving landward of the riverside guard wall and less tendency for crosscurrents to develop upstream of the end of the guard wall. Maximum velocities in the approach near the end of the riverside guard wall varied from about 1.5 fps with the 75,000-cfs flow to about 7.3 fps with the 465,000-cfs flow. Except for some reduction in velocities, conditions in the lower lock approach were about the same as with Plan A-3.

105. Navigation conditions in the upper lock approach were improved considerably compared with Plan A-3. Tows could approach the riverside upper guard wall from a considerable distance riverward of the right bank. Because of the high-velocity currents, downbound tows would tend to approach the riverside lock with speeds greater than considered desirable during the higher flows, and some flanking would be required to retard their forward motion. Tows approaching the landside lock would require some maneuvering unless properly aligned for the approach along the right bank line, particularly during the higher flows. Two-way traffic could be maintained in the upper approaches under most conditions and in the lower approaches during all conditions because of the separation provided by the common guide wall.

106. Based on observation of dye pattern, current direction and velocities, and the eddies that developed in the downstream lock approaches, shoaling would tend to occur in the approaches to the locks. However, shoaling in the lower approach would be less with the common guide wall than with a guard wall on the riverside lock, due to a more gradual increase in channel width

downstream of the locks. The wing wall at the downstream end of the riverward lock wall would also tend to reduce shoaling in the riverside lock approach.

## PART VII: DISCUSSION OF RESULTS AND CONCLUSIONS

### Limitation of Model Results

107. The analysis of the results of this investigation is based principally on a study of (a) the effects of various plans and modifications on water-surface elevations, current directions, and velocities; and (b) the effects of resulting currents on the behavior of the model towboat and barges. In evaluating test results, consideration should be given to the fact that small changes in direction of flow or in velocities are not necessarily changes produced by a modification in the plan since several floats introduced at the same point may follow a slightly different path and move at slightly different velocities because of pulsating currents and eddies. Current directions and velocities shown in the plates were obtained with floats submerged to the depth of a loaded barge (9 ft prototype) and are indicative of the currents that would affect the behavior of the tows.

108. The small scale of the model made it difficult to reproduce accurately the hydraulic characteristics of the prototype structures or to measure water-surface elevations within an accuracy greater than  $\pm 0.1$  ft prototype. The model was of the fixed-bed type and was not designed to simulate the movement of sediment in the prototype; therefore, changes in channel configurations and slopes resulting from changes in the channel bed and banks that might be caused by the structure or changes in flow conditions could not be determined in the model.

### Conclusions

109. The following conclusions and indications were developed during the investigation of the existing site:

- a. Navigation conditions for downbound tows approaching the existing locks were extremely difficult and could be hazardous, particularly with the high flows. This was caused by the high-velocity crosscurrents near the upstream end of the upper guard wall and the alignment of the tow in making the turn toward the locks. Some improvement in navigation conditions in the upper approach to the existing locks could be accomplished with submerged dikes located along the left bank in the approach to the locks, as in Plan E (Figure 5).

- b. Navigation conditions for downbound tows in the upper approach to the locks in the bypass canal as originally proposed (Plan E-1, Figure 7) would tend to be difficult and hazardous because of the crosscurrents near the entrance to the canal, limited canal width, and the short distance from the entrance of the canal to the locks. No serious difficulties were indicated in the lower approach for upbound tows approaching the locks, but some maneuvering and the attachment of mooring lines to the guide wall might be required for a satisfactory entrance into the locks.
- c. The crosscurrents near the entrance to the bypass canal could be reduced considerably and navigation conditions in the upper approach to the new locks improved by widening the entrance of the canal and providing a channel through the island between the river and the bypass canal as in Plan E-2 (Figure 9).
- d. Realigning the left bank excavation upstream of the bypass canal and extending it upstream to provide a straight approach to the bypass canal, as in Plan E-6 (Figure 13) and Plan E-7 (Figure 14), improved navigation conditions for tows entering and exiting the bypass canal.
- e. With two 1,200-ft locks in the bypass canal, a common upper guide wall as in Plan E-2 (Figure 9) and a common lower guide wall as in Plan E-3 (Figure 10) would provide separation of the traffic using alternate locks, and two-way traffic could be maintained under most conditions.
- f. With a 600-ft lock and a 1,200-ft lock located in the bypass canal, satisfactory navigation conditions could be provided with the arrangement of the locks, guide walls, and guard walls of Plan E-7 (Figure 14).
- g. With a single 1,200-ft lock in the bypass canal, satisfactory navigation conditions could be provided by the upper and lower lock approach configuration and arrangements of the guide and guard walls of Plan E-6 (Figure 13).
- h. Lowering the elevation of the entire upper lock approach canal from el 520 to el 506 as in Plan E-8 (Figure 15) to facilitate the movement of work vessels during an emergency would adversely affect navigation. However, lowering the upper lock approach canal to el 506 from the head of the island to the locks and providing a 500-ft-wide channel to the existing river channel in Plan E-9 (Figure 16) would provide access to the locks during emergency conditions without adversely affecting navigation.
- i. Filling either a single 1,200-ft lock or two 1,200-ft locks from the lock approach canal (Schemes 1 and 2, paragraphs 63 and 64) would create surges in water-surface elevation and current velocities that could be hazardous for tows in the upper lock approach.
- j. Filling a 600-ft auxiliary lock from the lock approach canal (Scheme 5, paragraph 66) would produce an adverse effect on a

tow located near the lock and could create hazardous conditions for a downbound tow moving in the lock approach depending on its location in the lock canal.

- k. Filling the 600- and 1,200-ft locks from the river channel as in Schemes 6 (paragraph 67) or 9 (paragraph 69) would have little or no effect on tows entering or leaving the new locks or the existing locks. There was no indication that either scheme would have a tendency to pull drift from the river channel, but ice that forms or drift windblown into the approach to the intake could be drawn into the intake structure.
- l. Emptying either the 600-ft lock or both the 600- and the 1,200-ft lock into the lower approach to the replacement locks as in Schemes 1, 2, 3, 8, or 9 created surges in water-surface elevation and current velocities that adversely affected tows entering and leaving the new locks.
- m. Emptying the 600- and 1,200-ft locks through a system located at the lower end of the island between the bypass canal and the river (Scheme 7, paragraphs 77 and 78 and Figure 18) produced no adverse effects on tows approaching or leaving the new locks, but emptying both locks simultaneously could have an adverse effect on tows approaching or leaving the existing locks during low riverflows.

110. The following conclusions were developed during the investigation of the alternate site:

- a. With the originally proposed plan (Plan A-1, Figure 21), navigation conditions for downbound tows approaching the locks would tend to be difficult and hazardous during the higher riverflows because of the limited width of the approach channel landward of the riverside lock guard wall and the alignment and high velocity of the currents in the approach. The bend in the right bank a short distance upstream of the lock approach also adversely affected navigation conditions.
- b. Satisfactory navigation conditions could be developed by moving the locks and dam downstream about 800 ft, excavating as much of the right bank as conditions would permit without affecting the highway along the bank, placing submerged dikes along the right bank upstream of the locks, and changing the arrangement of the lock auxiliary walls, as in Plan A-4 (Figure 25).
- c. A common lower guide wall as in Plan A-4 would provide separation of the traffic using alternate locks, and two-way traffic could be maintained with all conditions tested.
- d. The cells and fill at the downstream end of the wing wall of the riverside lock as in Plan A-4 would be required to reduce the tendency for the head of an upbound tow to be moved away from the guide wall as it approached the riverside lock.

Table 1  
Water-Surface Elevations, Base  
Test (Existing Site)

Gage No.*	Water-Surface Elevation for Discharge, 1,000 cfs					
	75	217	300	433	466	500
1	538.3	538.6	545.7	556.8	559.4	561.9
2	538.2	538.4	545.6	556.5	559.2	561.7
3	538.2	538.2	545.5	556.3	559.1	561.5
4	538.1	538.0	545.4	556.2	558.9	561.4
A	538.0**	538.0	545.4	556.2	558.9	561.4
5	537.9	537.6	544.7	555.5	558.1	560.5
6	522.7	537.3	544.5	555.1	557.9	560.5
B	522.7**	537.0**	544.1**	554.8**	557.5**	560.1**
7	522.7	537.0	544.1	554.8	557.4	560.0
8	522.5	537.0	544.1	554.6	557.4	559.9

---

\* Gage locations shown in Figure 2.  
 \*\* Controlled elevations.

Table 2  
Results of Lock Filling Tests

Discharge cfs	Scheme 1 (Plan E-1)		Maximum and Minimum Water-Surface Elevations		Tailwater Elevations	
	Scheme 2 (Plan E-2)		Scheme 3 (Plan E-4)			
	Canal	Lock*	Canal	Lock*		
16,000	538.0-538.1**	538.0-538.1**	538.0-538.1**	538.0-538.1**	515.0	
	536.2-538.7	538.8-538.0	538.0-538.1	538.8-538.0		
217,000	538.5-538.6**	538.5-538.7**	538.5-538.7**	538.4-538.6**	537.0	
	538.5-538.6	538.8-538.5	-- --	-- --		
300,000			538.6-538.3	-- --	538.5-538.2	
				545.7-546.0**	544.1	
433,000				-- --	545.7-545.5	
				556.4-556.9**	554.6	
466,000	558.9-559.4**	558.9-559.6**	558.9-559.6**	-- --	556.6-556.3	
	559.2-558.9	-- --	559.0-558.7			
					557.4	

\* End of lock filling operation (8-15 min after start of valve opening).  
\*\* Normal variations in canal caused by surges (without lock filling).

Table 3

Surge in Lower Lock Approaches during Lock Emptying with 23-ft Head

Emptying*	Surge, Feet Above Normal Lower Pool, El 315.0, for Scheme No.									
	1		2		3		4		5	
	Land	River	Land	River	Land	River	Land	River	Land	River
Lock	Lock	Lock	Lock	Lock	Lock	Lock	Lock	Lock	Lock	Lock
Land lock	0.6	0.3	0.6	0.2	0.6	0.2	0.2	0.4	0.3	0.4
Both locks	1.0	0.7	0.9	0.7	1.0	0.5	0.6	0.6	0.6	0.6
River lock	0.3	0.6	0.3	0.5	0.4	0.2	0.2	0.4	0.3	0.4

\* Emptying times for the schemes were as follows: Scheme 1, 9 min 20 sec; Scheme 2, 9 min 20 sec; Scheme 3, 9 min; Scheme 4, 8 min 20 sec; and Scheme 5, 9 min 30 sec.

Table 4  
Water-Surface Elevations, Base  
Test (Alternate Site)

Gage No.*	Water-Surface Elevation for Discharge, 1,000 cfs				
	75	232	300	465	500
1	522.8	537.8	543.6	556.8	559.6
2	522.6	537.5	543.2	556.6	559.2
3	522.6	537.4	543.2	556.4	559.2
4	522.5	537.3	543.1	556.3	559.0
5	522.4	537.1	543.0	556.1	558.9
6	522.4	537.1	542.9	556.1	558.8
7	522.2**	537.0**	542.8**	555.9**	558.7**
8	522.1	536.7	542.6	555.6	558.5
9	522.0	536.6	542.5	555.5	558.4
10	522.0	536.4	542.1	555.4	558.3

---

\* Gage locations shown in Figure 3.

\*\* Controlled elevation.

Table 5  
Water-Surface Elevations  
Plan A-1

Gage No.	Water-Surface Elevation for Discharge, 1,000 cfs		
	232	465	500
1	538.2	557.2	560.5
2	537.9	556.9	560.2
3	537.9	556.9	560.1
4	537.8	556.6	559.8
5	537.2	556.1	559.0
6	536.9	555.7	558.5
7	536.7	555.6	558.4
8	536.6	555.5	558.4
9	536.6	555.4	558.4
10	536.4*	555.4*	558.3*

---

\* Controlled elevation.

Table 6  
Water-Surface Elevations  
Plan A-2

Gage No.	Water-Surface Elevation for Discharge, 1,000 cfs			
	75	232	465	500
1	538.2	538.4	557.3	560.3
2	538.1	537.9	556.9	559.9
3	538.0	537.7	556.7	559.7
4	538.0*	537.5	556.5	559.5
5	538.0	537.2	556.0	559.1
6	522.2	536.9	555.6	558.6
7	522.2	536.8	555.5	558.5
8	522.2	536.7	555.5	558.5
9	522.1	536.6	555.4	558.5
10	522.0*	536.4*	555.4*	558.3*

---

\* Controlled elevation.

Table 7  
Water-Surface Elevations  
Plan A-3

Gage No.	Water-Surface Elevation for Discharge, 1,000 cfs			
	75	232	465	500
1	538.1	538.2	557.4	560.4
2	538.1	538.0	557.2	560.1
3	538.0	538.0	557.1	559.9
4	538.0*	537.9	557.0	559.8
5	538.0	537.3	556.1	559.1
6	522.2	536.9	555.7	558.5
7	522.1	536.6	555.6	558.4
8	522.1	536.6	555.6	558.4
9	522.0	536.5	555.6	558.4
10	522.0*	536.4*	555.4*	558.3*

\* Controlled elevation.

Table 8  
Water-Surface Elevations  
Plan A-4

Gage No.	Water-Surface Elevation for Discharge, 1,000 cfs			
	75	232	465	500
1	538.1	538.3	557.3	560.2
2	538.1	538.0	557.2	559.8
3	538.0	537.8	556.9	559.7
4	538.0*	537.7	556.8	559.5
5	538.0	537.2	556.0	559.1
6	522.2	537.0	555.6	558.5
7	522.2	536.7	555.6	558.5
8	522.1	536.6	555.6	558.4
9	522.1	536.5	555.6	558.3
10	522.0*	536.4*	555.4*	558.3*

\* Controlled elevation.



Photo 1. Base test (existing condition). Discharge 217,000 cfs, upper pool el 538.0. Note path of large downbound tow approaching landside lock and tendency for the head of tow to be moved riverward of the guide wall



Photo 2. Base test (existing condition). Discharge 217,000 cfs, lower pool el 537.0. Path of upbound tow approaching landside lock from along left bank

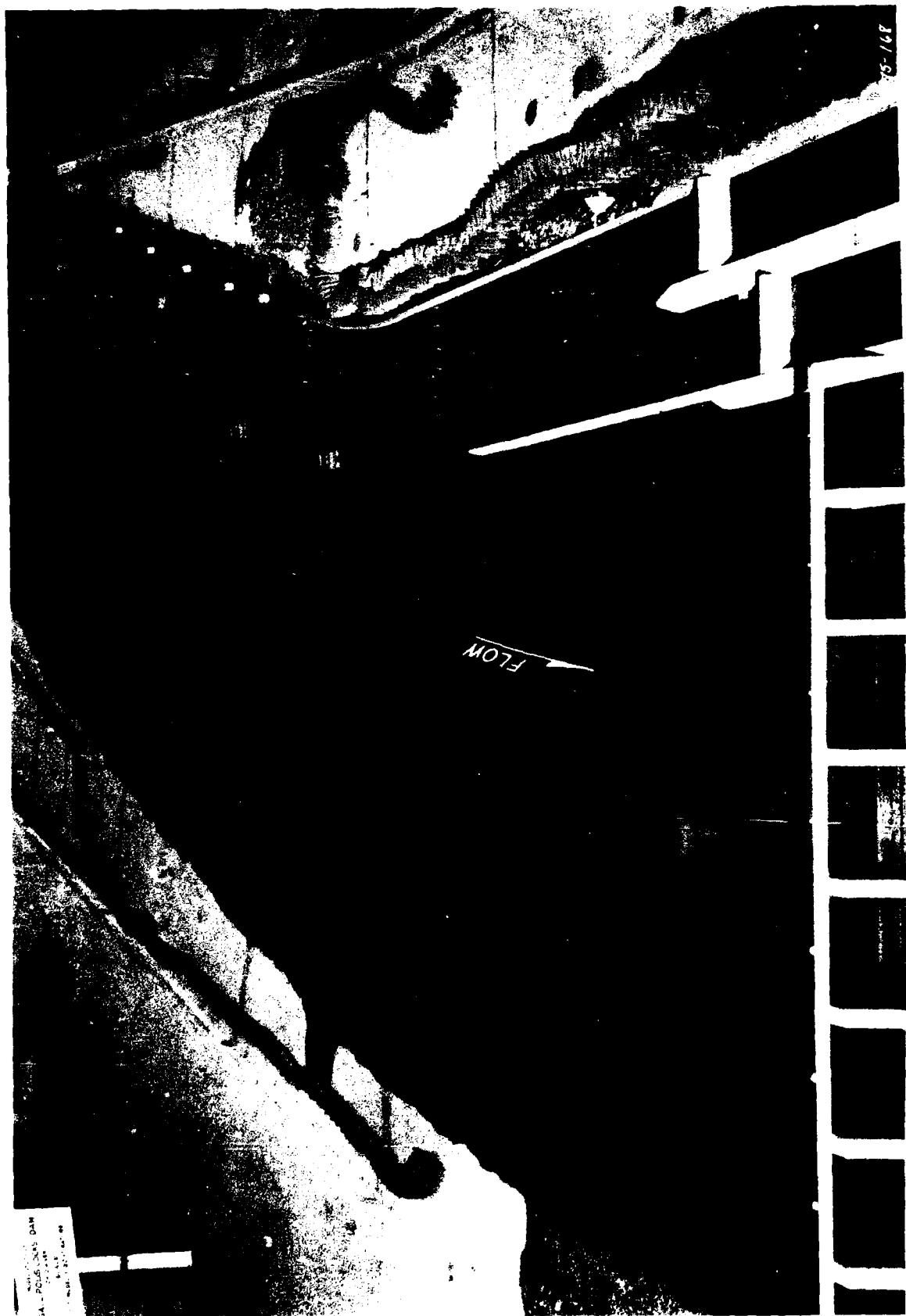


Photo 3. Plan E. Discharge 217,000 cfs, upper pool el 538.0. Path of large downbound tow approaching the main lock without the aid of mooring lines

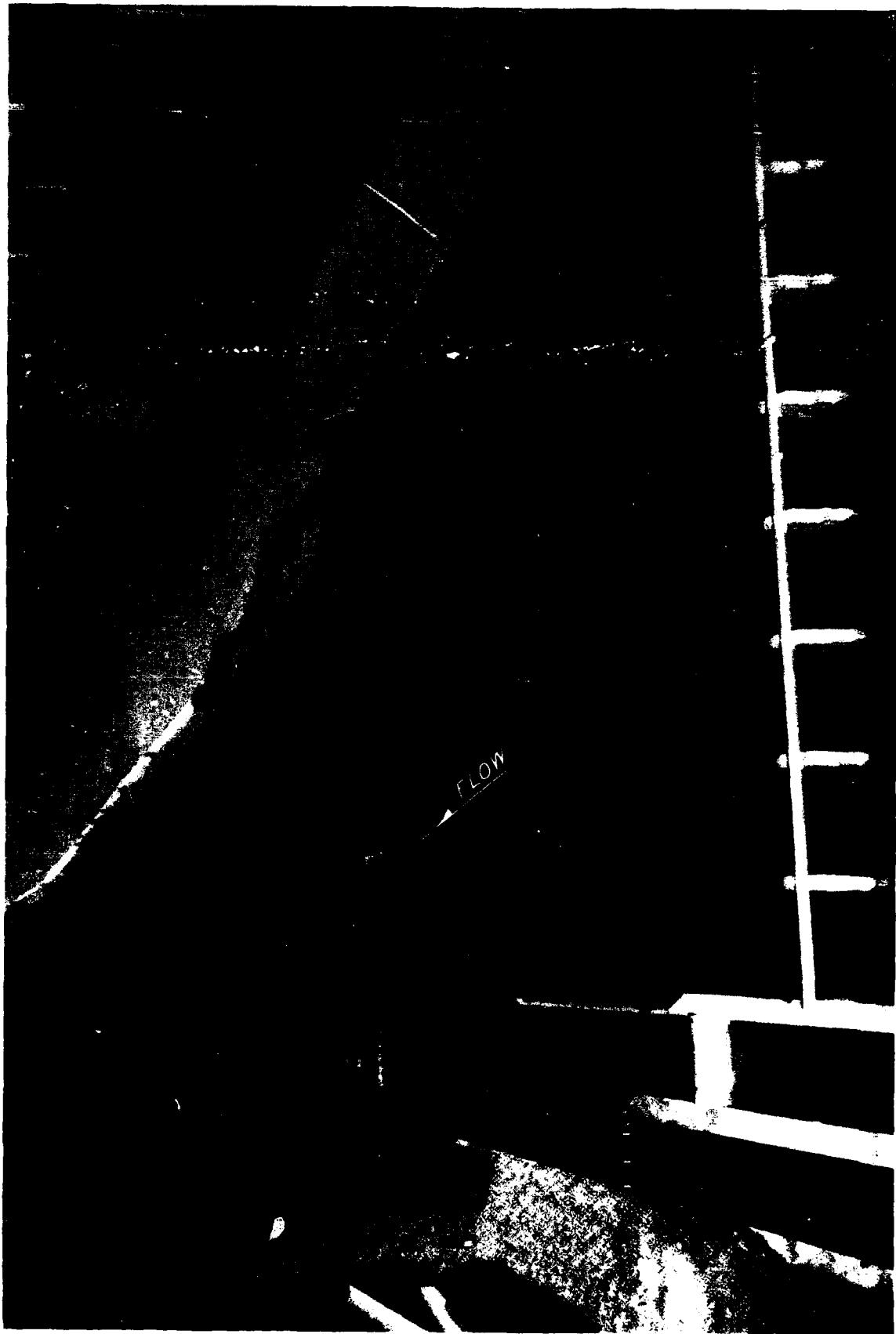


Photo 4. Plan E. Discharge 217,000 cfs, lower pool el 537.0. Path of upbound tow approaching landside lock

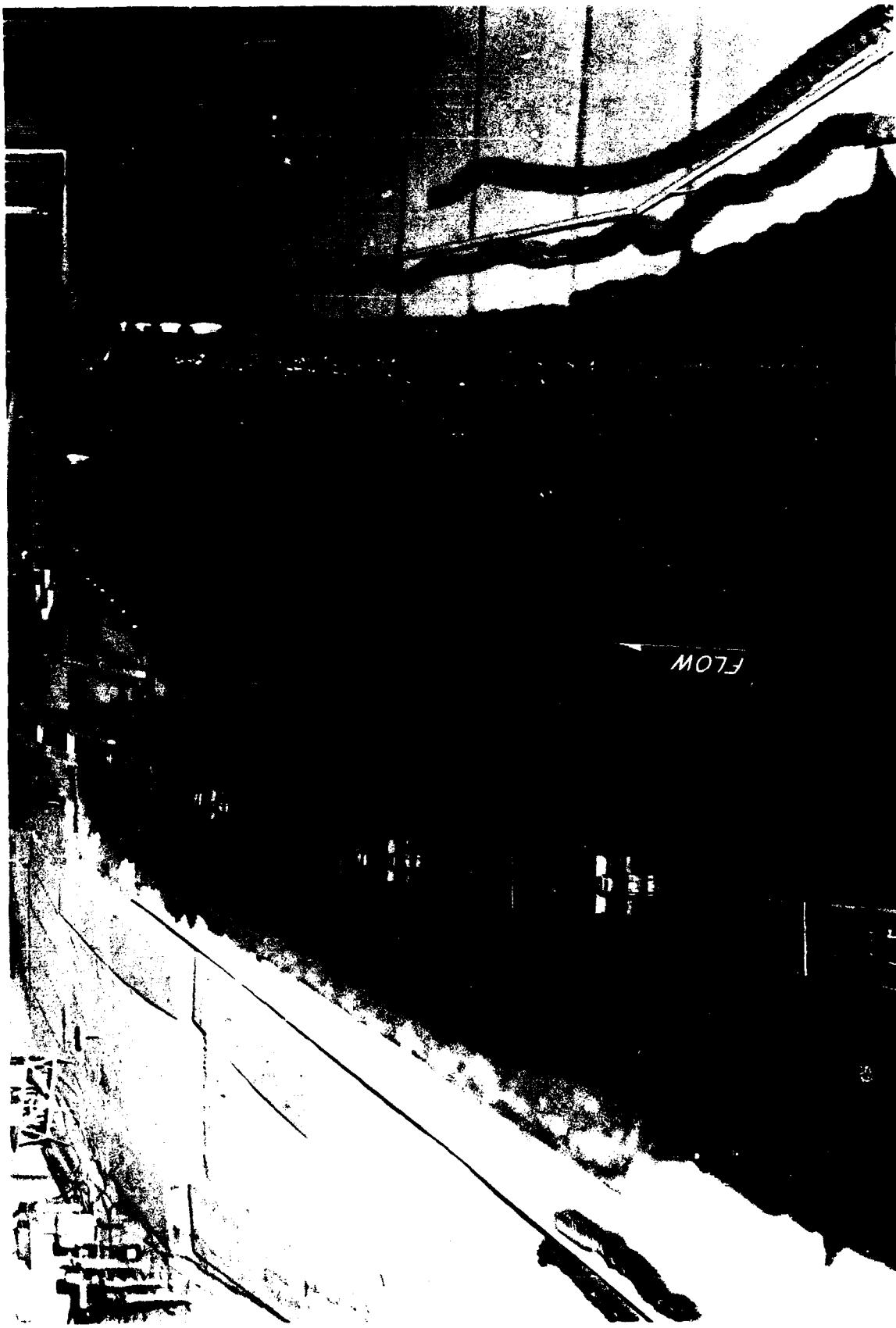


Photo 5. Plan E-4. Discharge 217,000 cfs, upper pool el 538.0. Path of downbound tow approaching the proposed new lock from a considerable distance riverward of the left bank of the bypass canal



Photo 6. Plan E-4. Discharge 217,000 cfs, lower pool el 537.0. Path of upbound tow approaching the proposed new lock. Note distance from the left bank at which tow has to approach lower guide wall



Photo 7. Plan E-5. Discharge 217,000 cfs, upper pool el 538.0. Path of downbound tow approaching the proposed new lock. Note maneuvering required to approach upper guide wall



Photo 8. Plan E-5. Discharge 217,000 cfs, lower pool el 537.0. Path of upbound tow approaching the proposed new lock from close along the left bank

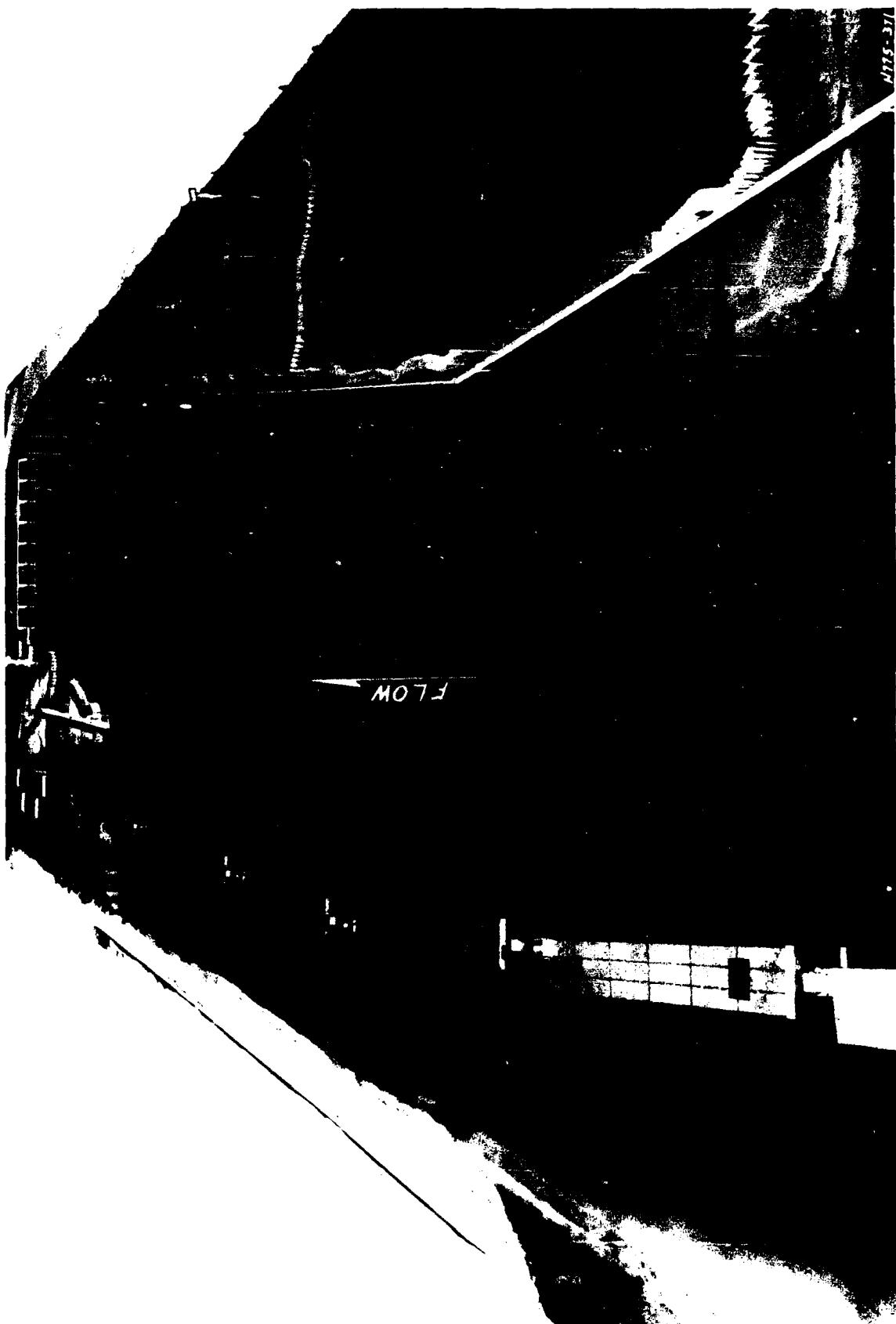


Photo 9. Plan E-7. Discharge 466,000 cfs, upper pool el 558.9. Path of downbound tow approaching the main lock. Note the distance from the left bank to the path of the tow



Photo 10. Plan E-7. Discharge 466,000 cfs, upper pool el 558.9. Path of downbound tow approaching the 600-ft lock

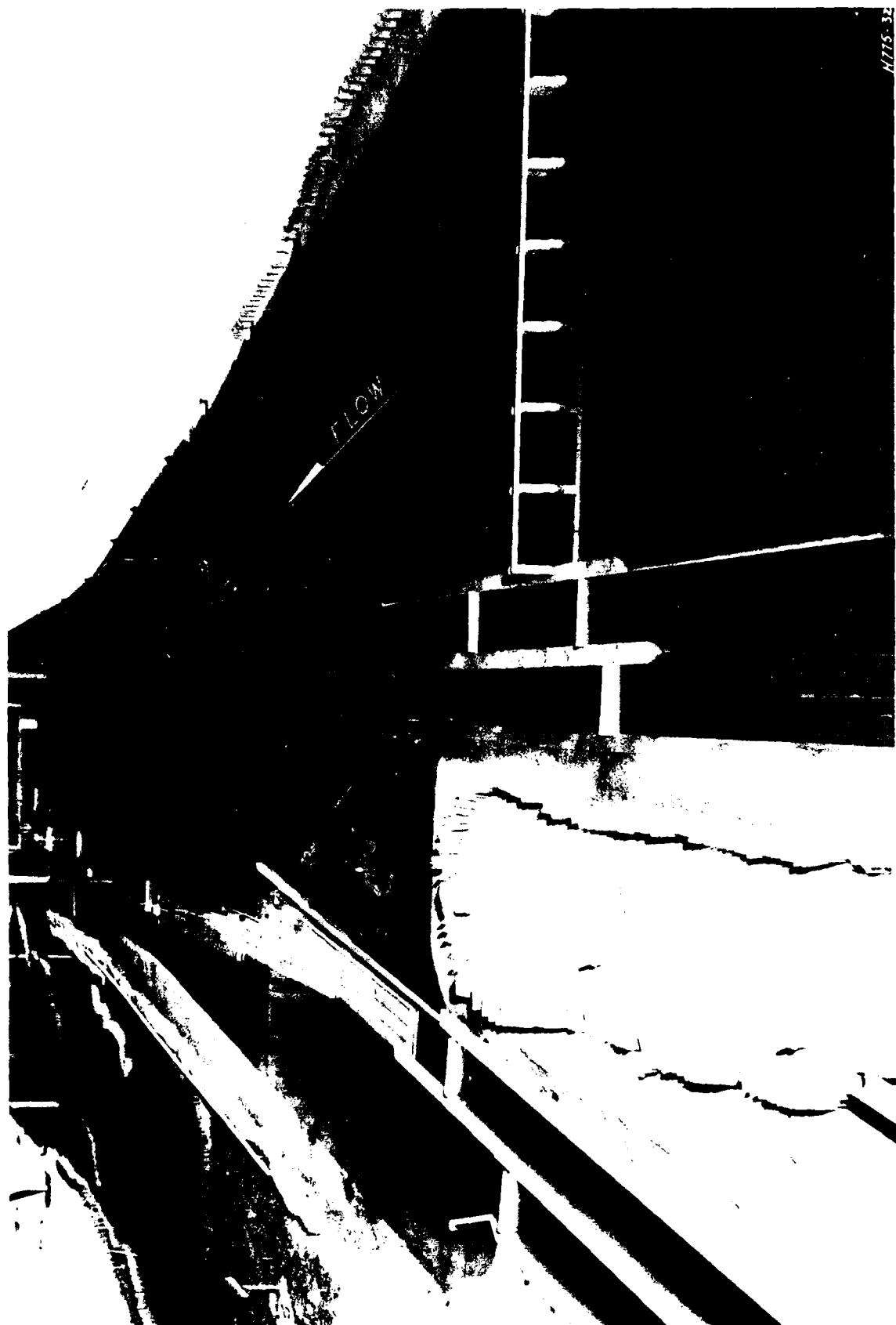


Photo 11. Plan E-7. Discharge 466,000 cfs, lower pool el 557.4. Path of upbound tow approaching the main lock

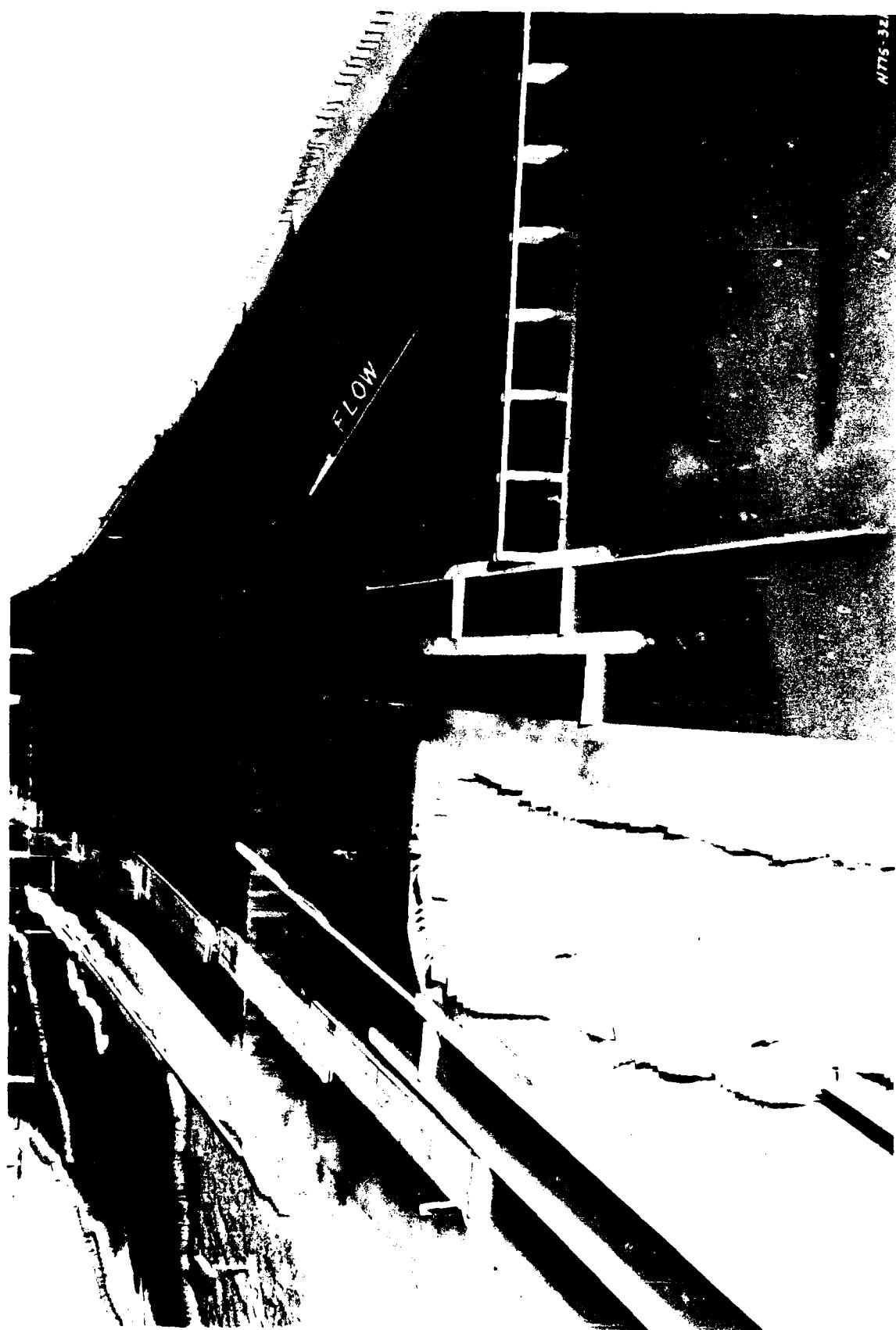


Photo 12. Plan E-7. Discharge 466,000 cfs, lower pool el 557.4. Path of upbound tow approaching the 600-ft lock



Photo 13. Plan E-7. Discharge 466,000 cfs, lower pool el 557.4. Path of two-way traffic with upbound tow approaching the main lock

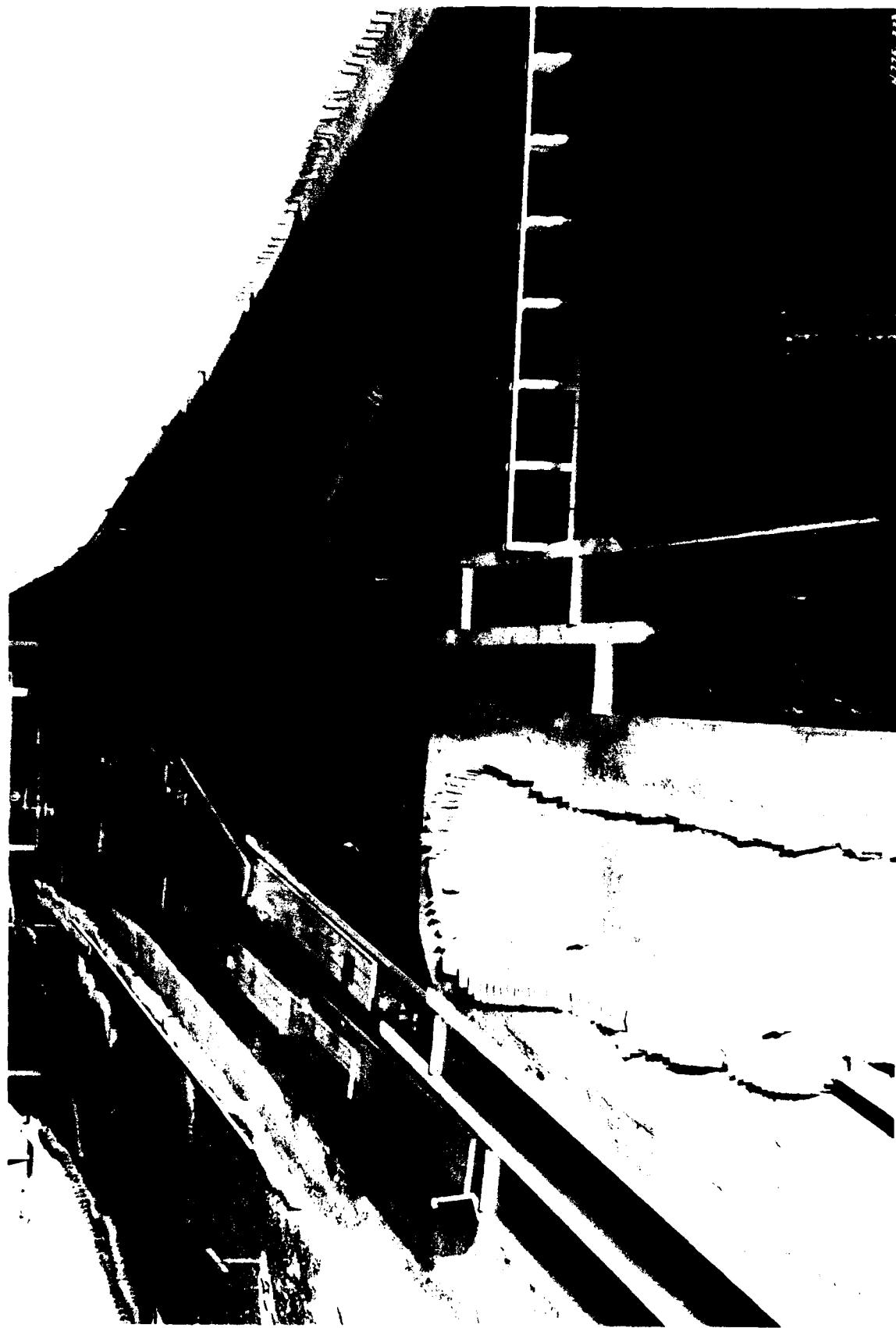


Photo 14. Plan E-7. Discharge 466,000 cfs, lower pool el 557.4. Path of two-way traffic with upbound tow approaching the 600-ft lock



Photo 15. Plan E-9. Discharge 217,000 cfs, upper pool el 338.0.  
Path of downbound tow approaching 1,200-ft lock

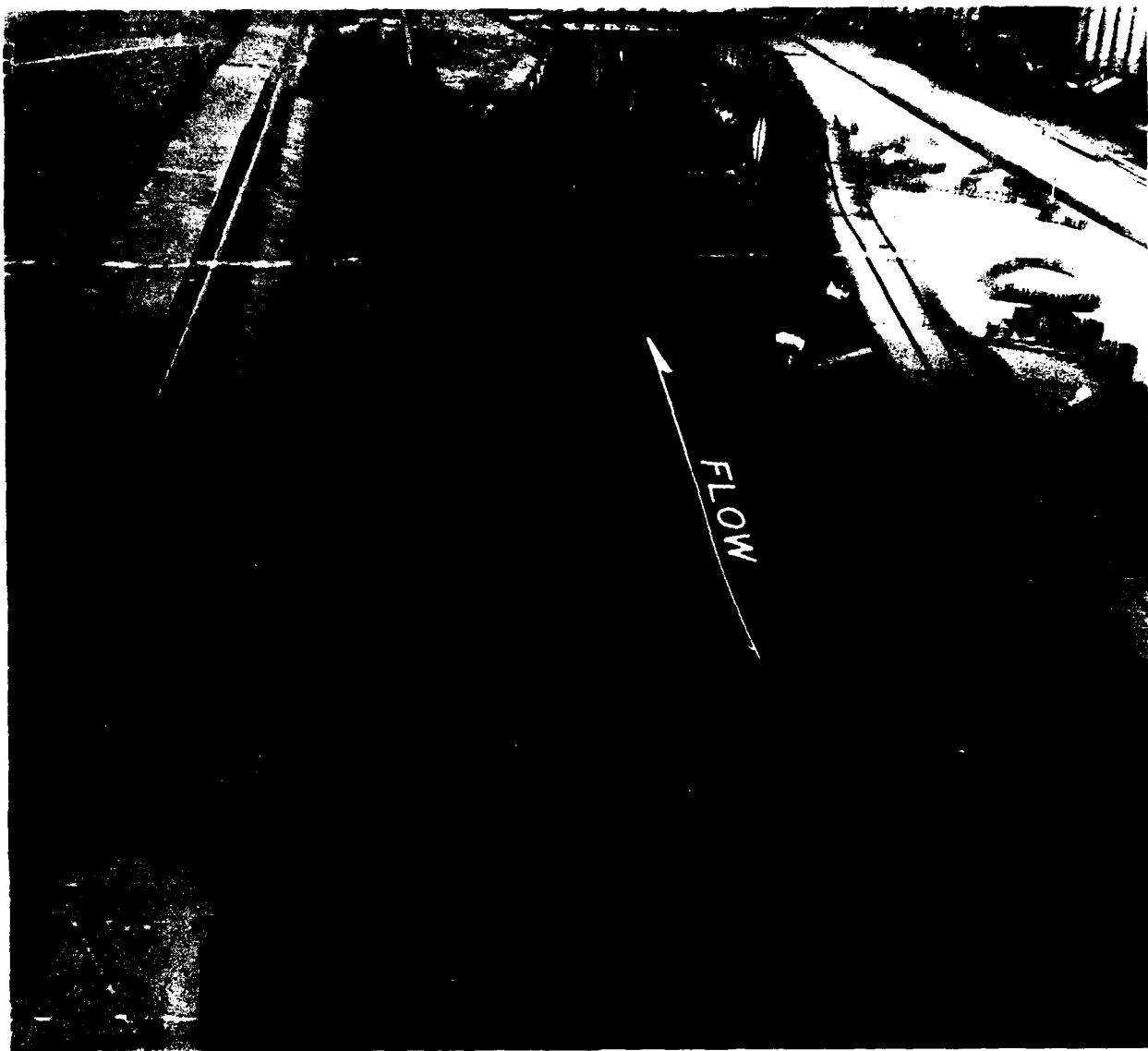


Photo 16. Plan E-9. Discharge 217,000 cfs, upper pool el 338.0.  
Path of downbound tow approaching 600-ft lock



Photo 17. Plan E-9. Discharge 217,000 cfs, upper pool el 338.0.  
Path of upbound tow leaving 1,200-ft lock



Photo 18. Plan E-9. Discharge 217,000 cfs, upper pool el 338.0.  
Path of upbound tow leaving 600-ft lock



Photo 19. Plan E-9. Discharge 217,000 cfs, upper pool el 338.0. Path of tows passing in upper approach to locks, with downbound tow approaching 600-ft lock



Photo 20. Plan E-9. Discharge 217,000 cfs, upper pool el 338.0. Path of tows passing in upper approach to locks, with downbound tow approaching 1,200-ft lock

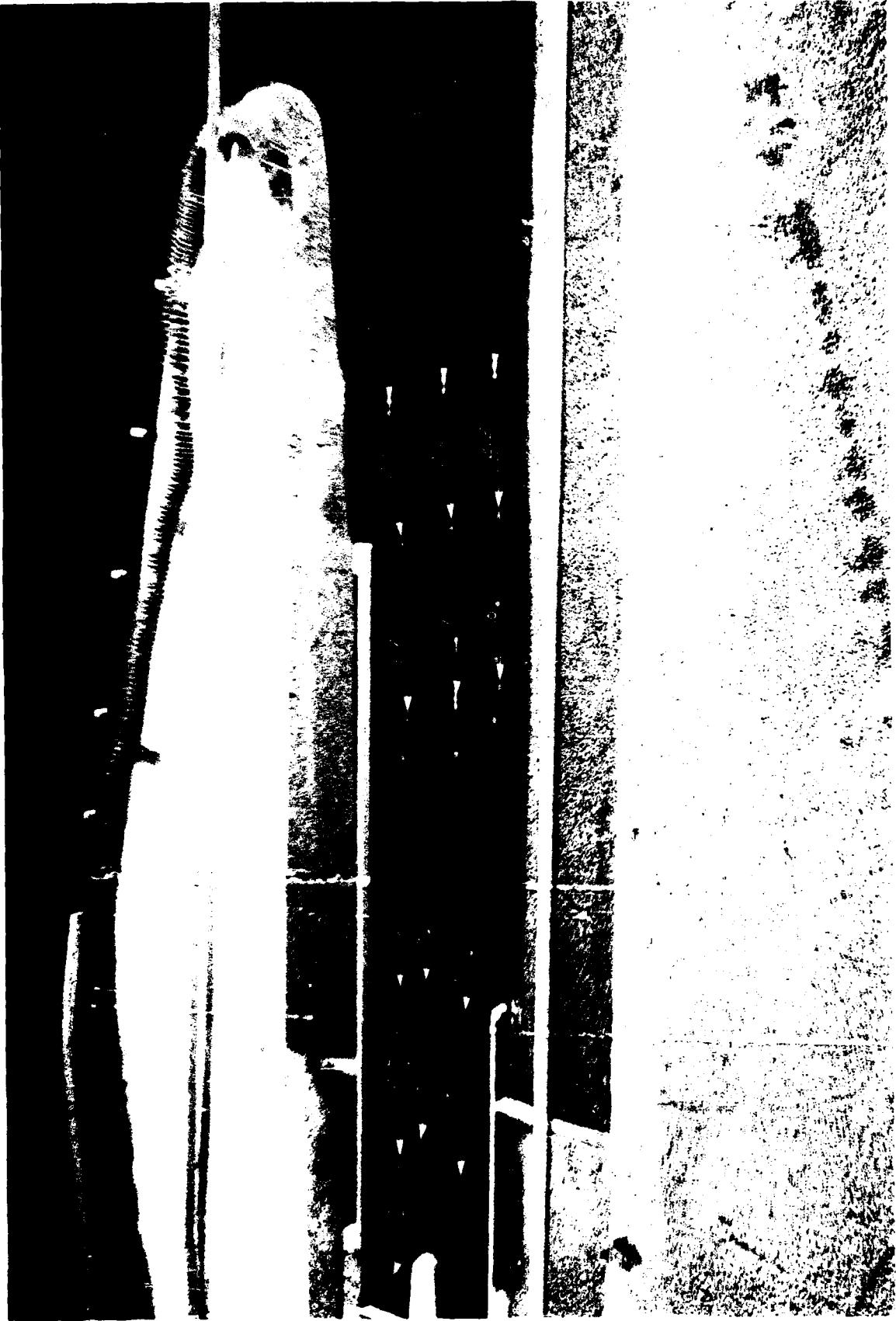


Photo 21. Plan E-1, Scheme 1. Discharge 16,000 cfs, upper pool el 538.0, lower pool el 515.0. Current velocities in the upper lock approach resulting from filling of the riverside lock in 9 min

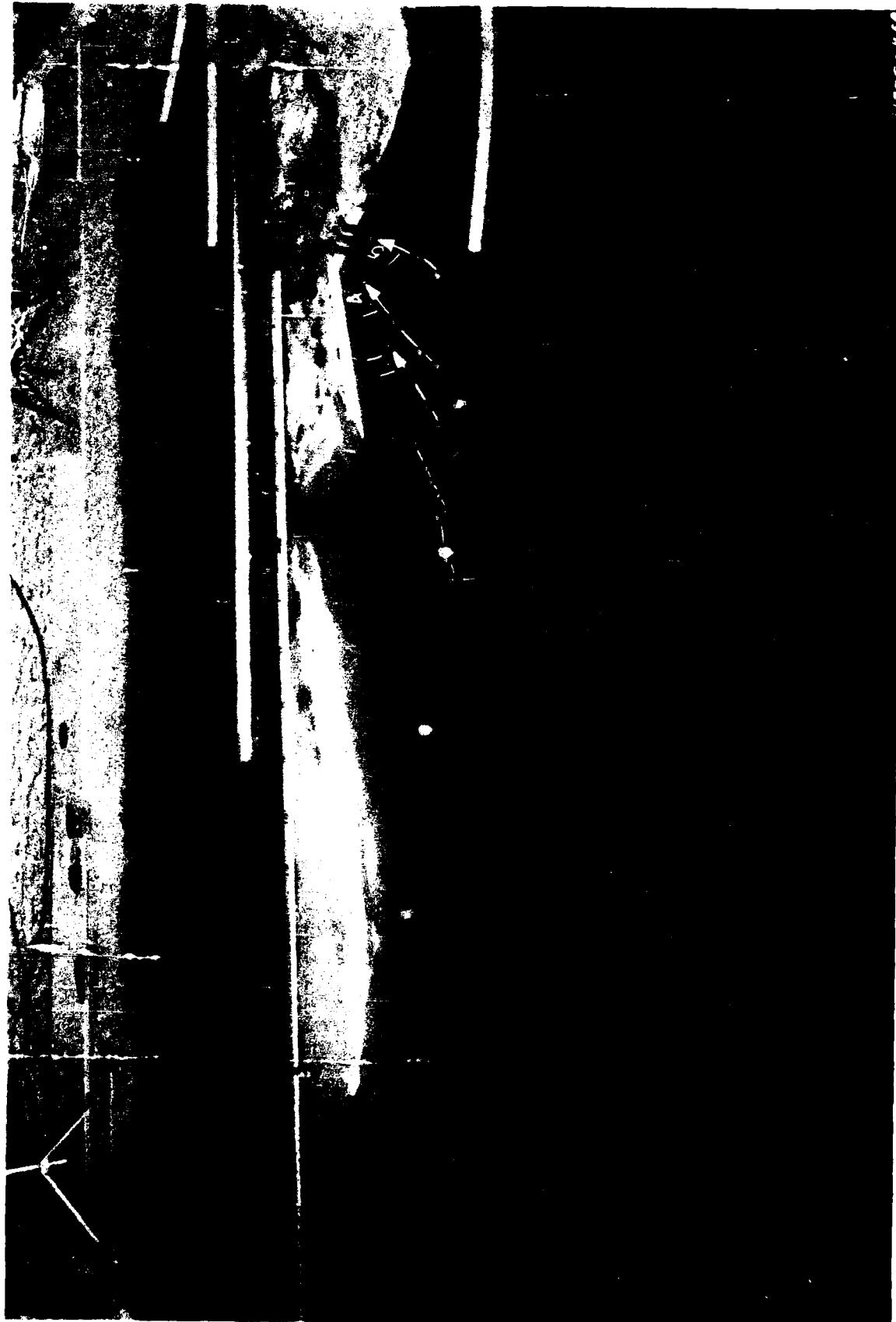


Photo 22. Plan E-7 modified, Scheme 4. Discharge 16,000 cfs, upper pool el 538.0, lower pool el 515.0. Current velocities in approach to filling intake resulting from filling both new locks simultaneously in 8 min



Photo 23. Plan E-7 modified, Scheme 5. Discharge 16,000 cfs, upper pool el 538.0, lower pool el 515.0. Current velocities in the upper lock approach resulting from filling the 600-ft lock in 8 min



Photo 24. Plan E-7 modified, Scheme 5. Discharge 16,000 cfs, upper pool el 538.0, lower pool el 515.0.  
Note path of tow resulting from filling the 600-ft lock in 8 min

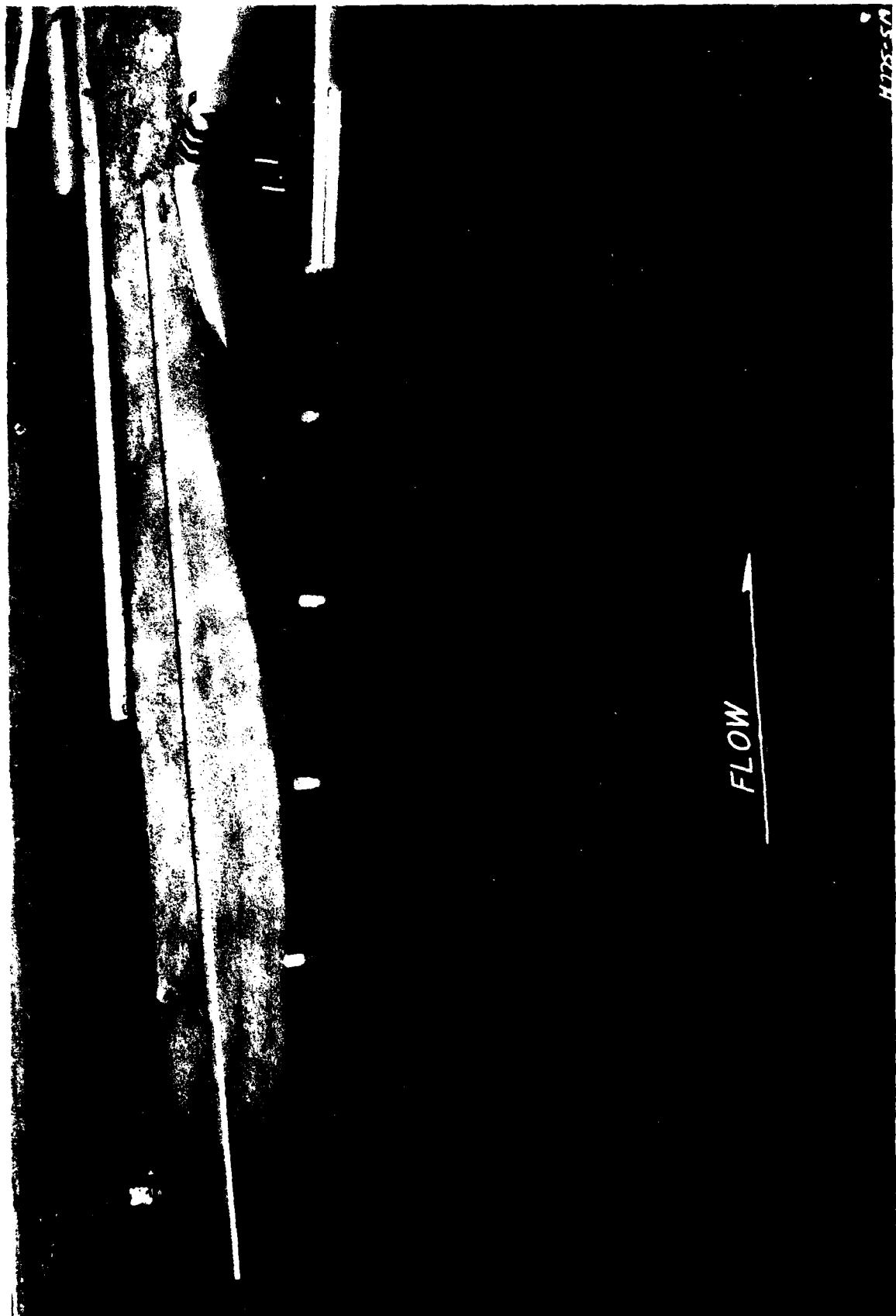


Photo 25. Plan E-9 modified, Scheme 6. Discharge 16,000 cfs, upper pool el 538.0, lower pool el 515.0. Current velocities in approach to filling intake resulting from filling both new locks simultaneously in 8 min

FLOW

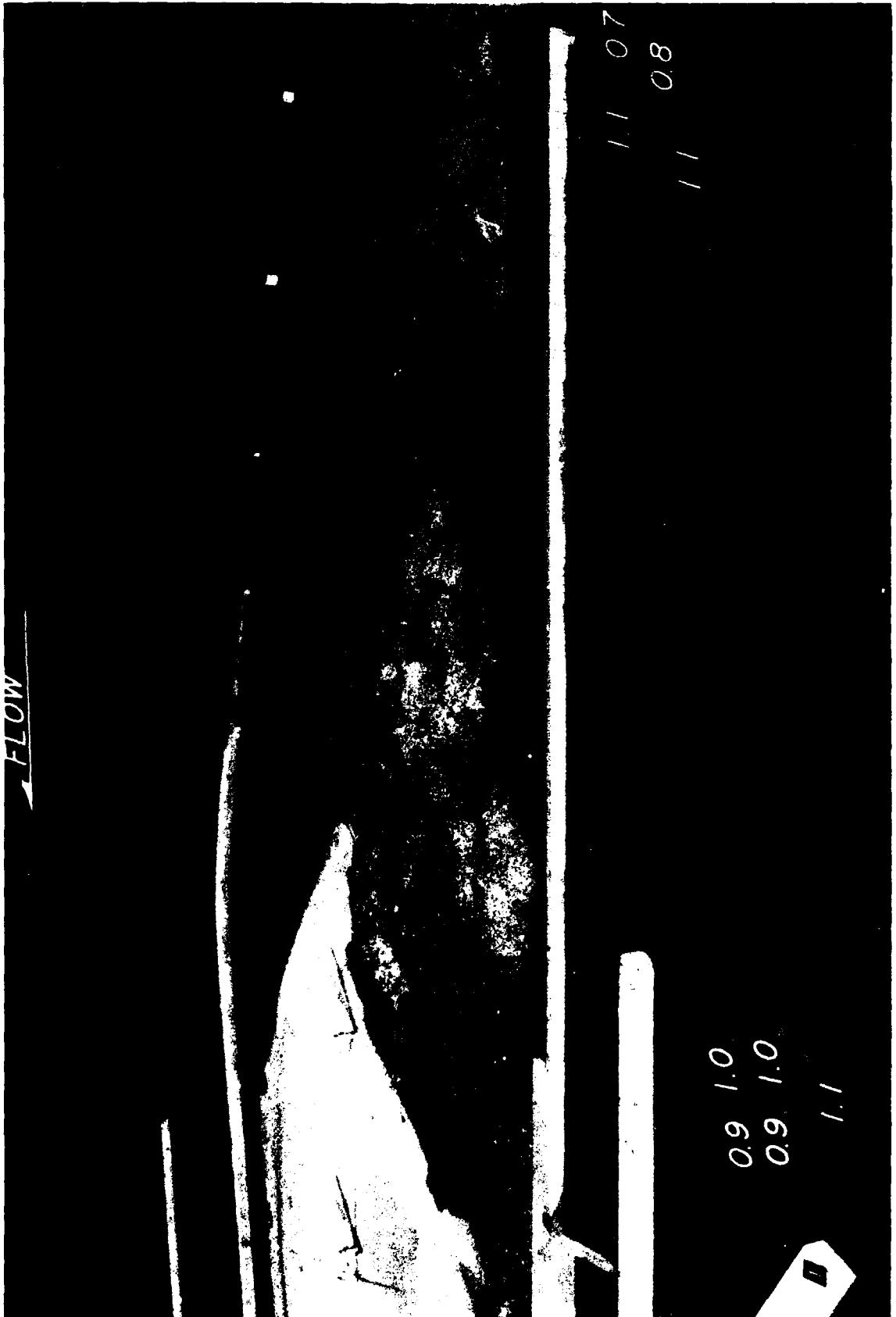


Photo 26. Plan E-9 modified, Scheme 7. Discharge 16,000 cfs, upper pool el 538.0, lower pool el 515.0. Current velocities in upper lock approach resulting from filling the 600-ft lock through the wing wall intake in 8 min



Photo 27. Plan E-9 modified, Scheme 7. Discharge 16,000 cfs, upper pool el 538.0, lower pool el 515.0.  
Path of tow resulting from filling the 600-ft lock through wing wall intake in 8 min



Photo 28. Plan E-9 modified, Scheme 8. Discharge 16,000 cfs, upper pool el 538.0, lower pool el 515.0. Current velocities in the upper lock approach resulting from filling the 600-ft lock through the landward lock wall intake in 8 min

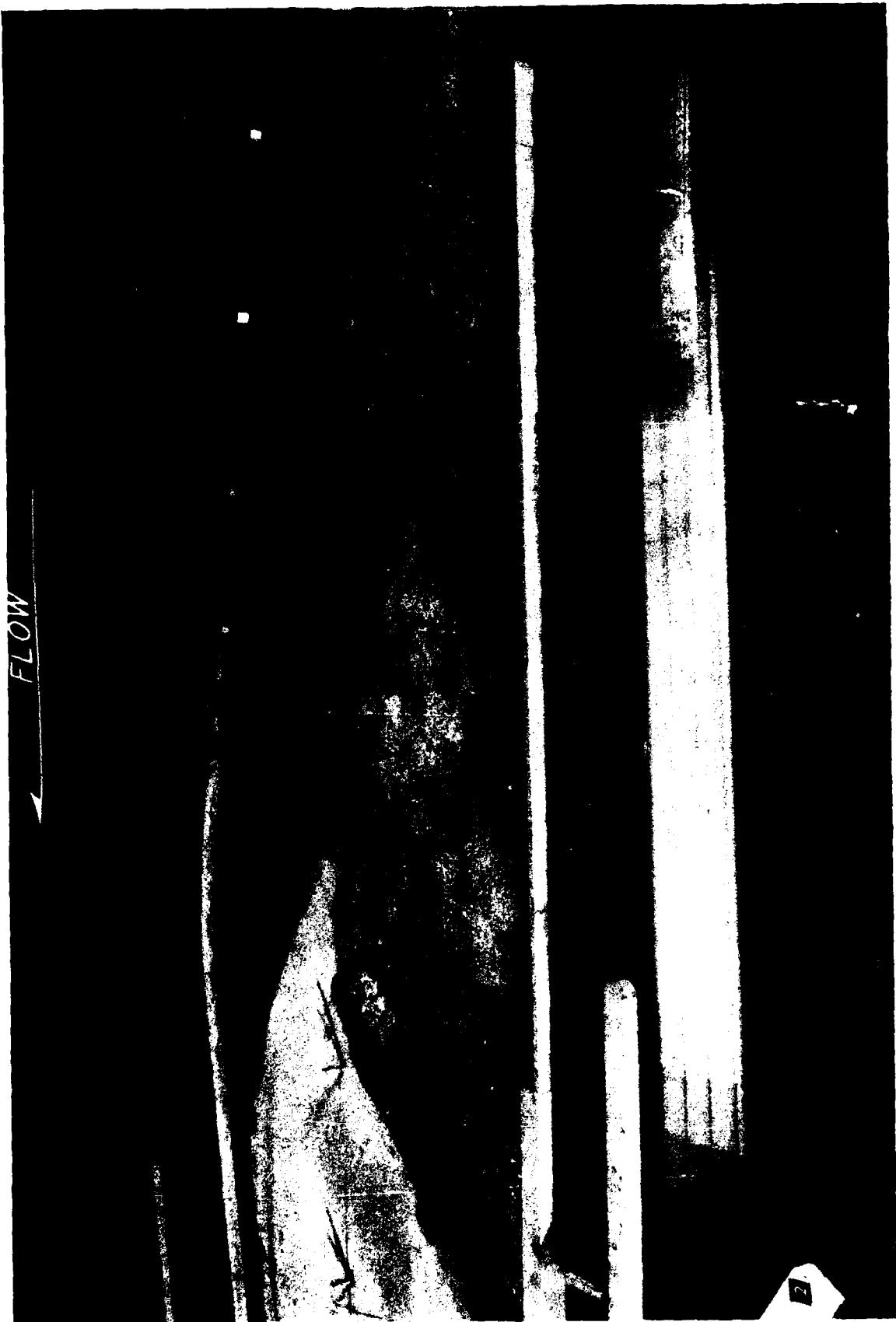


Photo 29. Plan E-9 modified, Scheme 8. Discharge 16,000 cfs, upper pool el 538.0, lower pool el 515.0.  
Path of tow resulting from filling the 600-ft lock through landward lock wall intake in 8 min

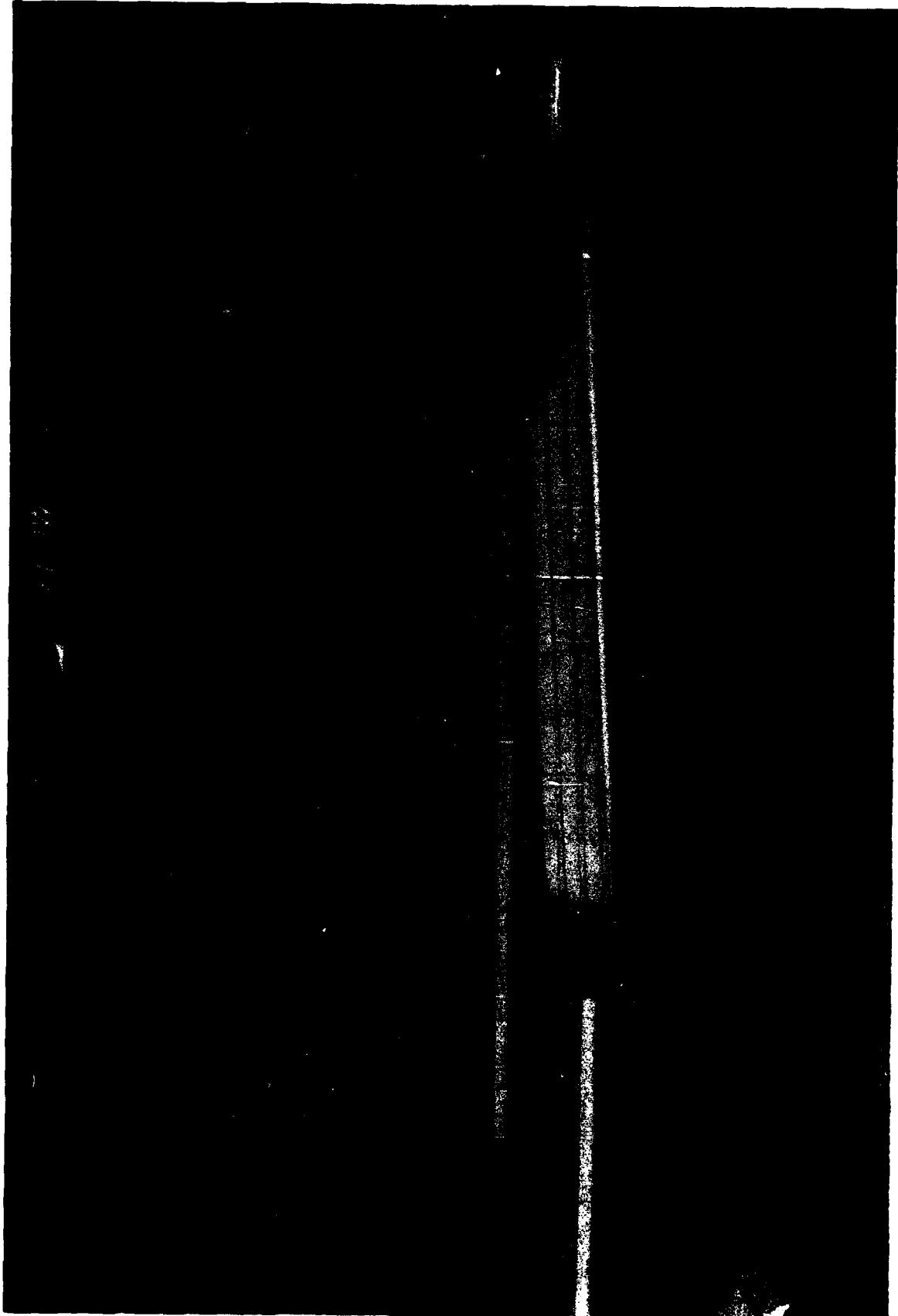


Photo 30. Plan E-9 modified, Scheme 8. Discharge 16,000 cfs, upper pool el 538.0, lower pool el 515.0. Path of tow along the right bank resulting from filling the 600-ft lock through landward lock wall intake in 8 min



Photo 31. Plan E-10 modified, Scheme 9. Discharge 16,000 cfs, upper pool el 538.0, lower pool el 515.0. Current velocities and dye patterns in the approach to the filling intakes resulting from filling both new locks simultaneously in 8 min

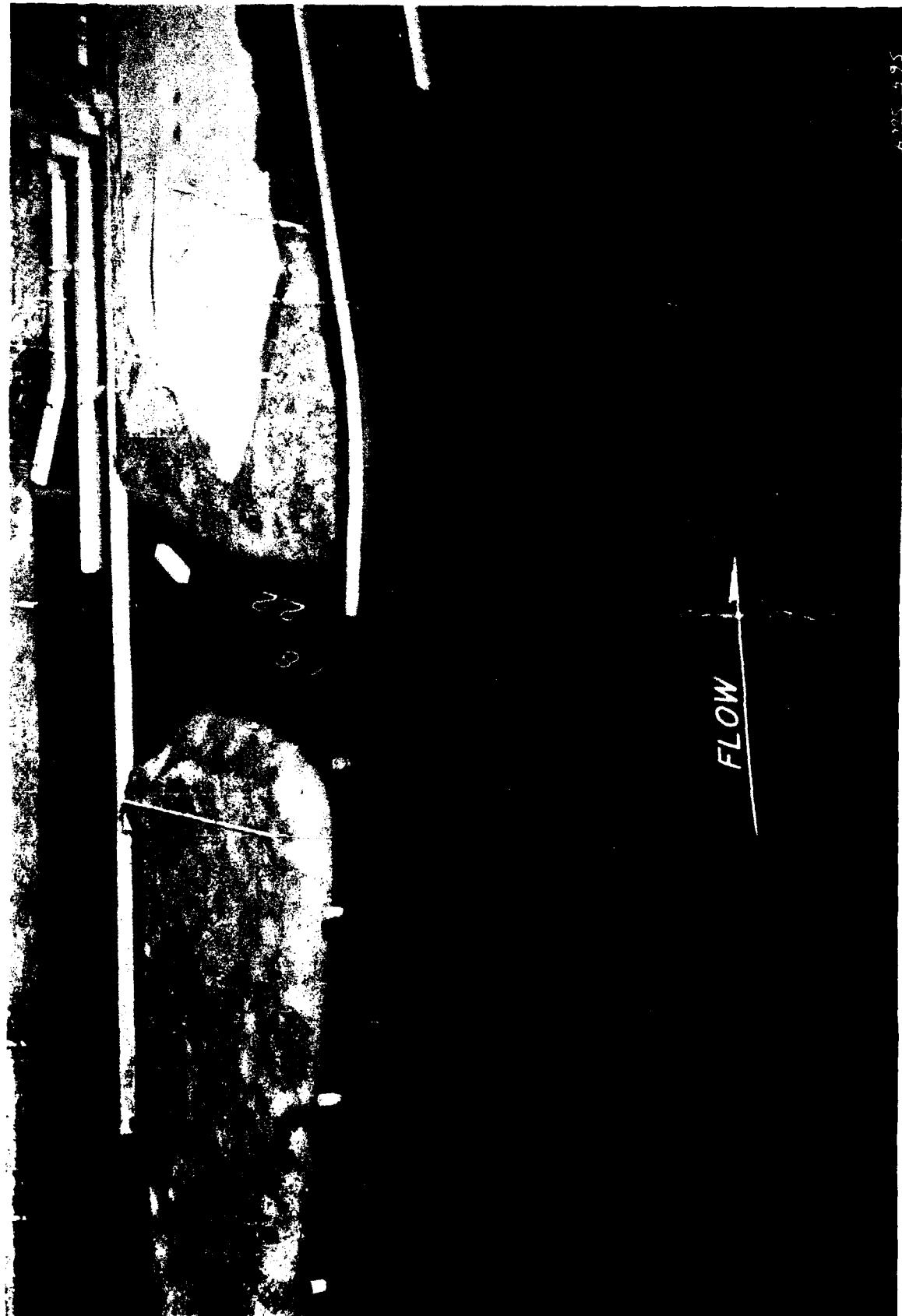


Photo 32. Plan E-10 modified, Scheme 9. Discharge 16,000 cfs, upper pool el 538.0, lower pool el 515.0. Current velocities and dye patterns in the approach to the filling intakes resulting from filling the 1,200-ft lock in 8 min

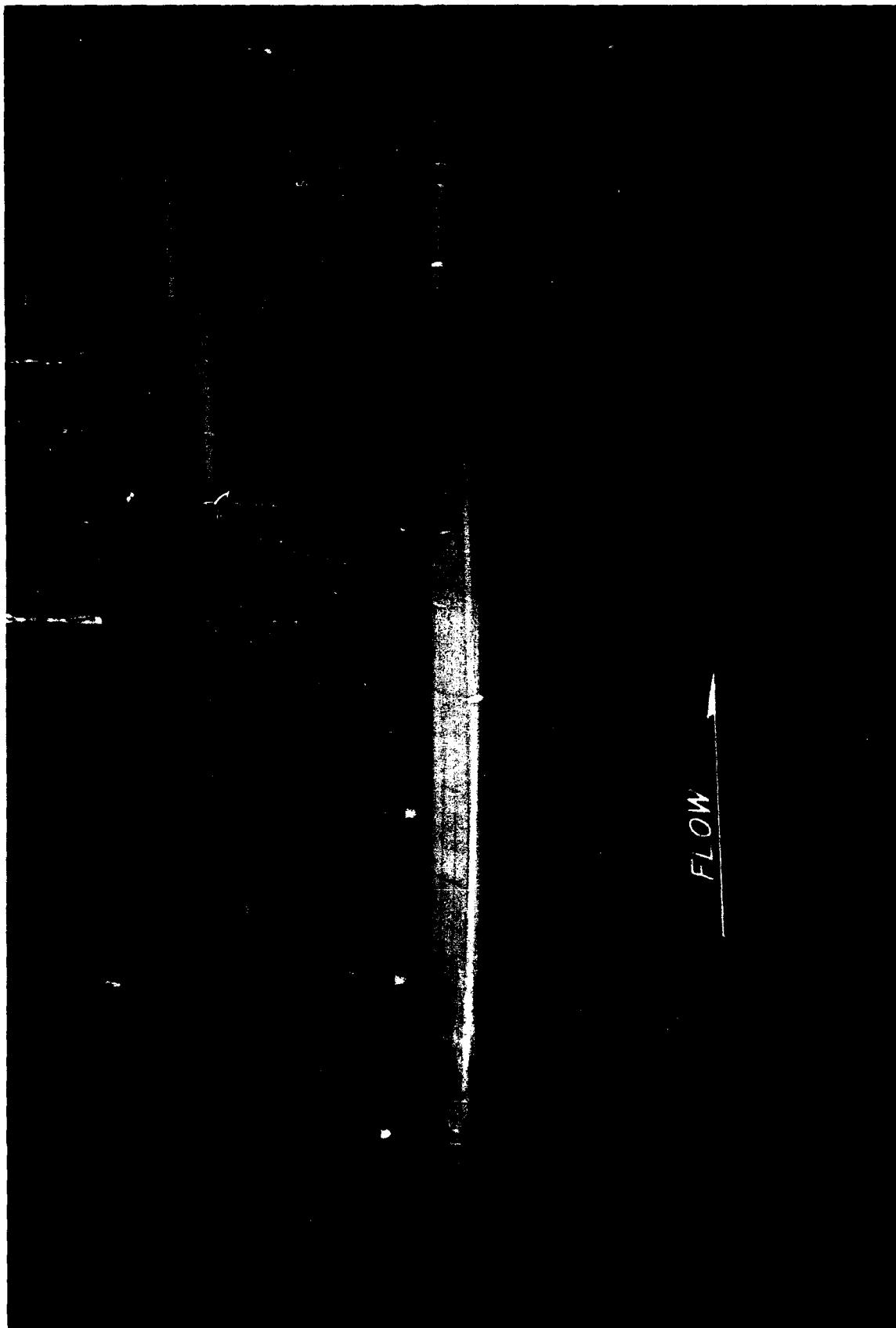


Photo 33. Plan E-10 modified, Scheme 9. Discharge 16,000 cfs, upper pool el 538.0, lower pool el 515.0.  
Path of tow approaching the existing locks resulting from filling both new locks simultaneously in 8 min

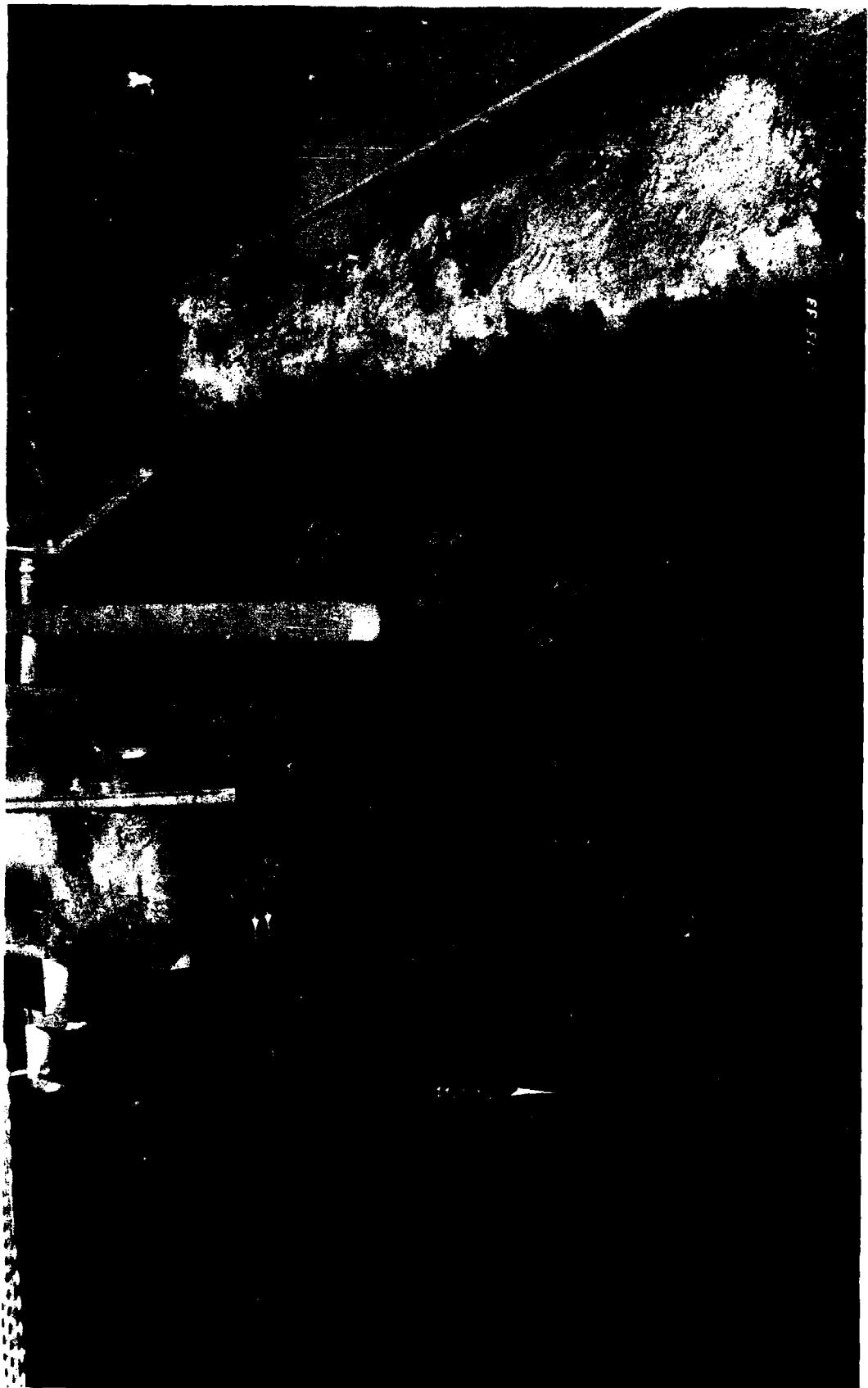


Photo 34. Plan E-3, Scheme I. No river discharge, upper pool el 538.0, lower pool el 515.0. Current velocities in the lower approach to the locks resulting from emptying both locks simultaneously in 8 min

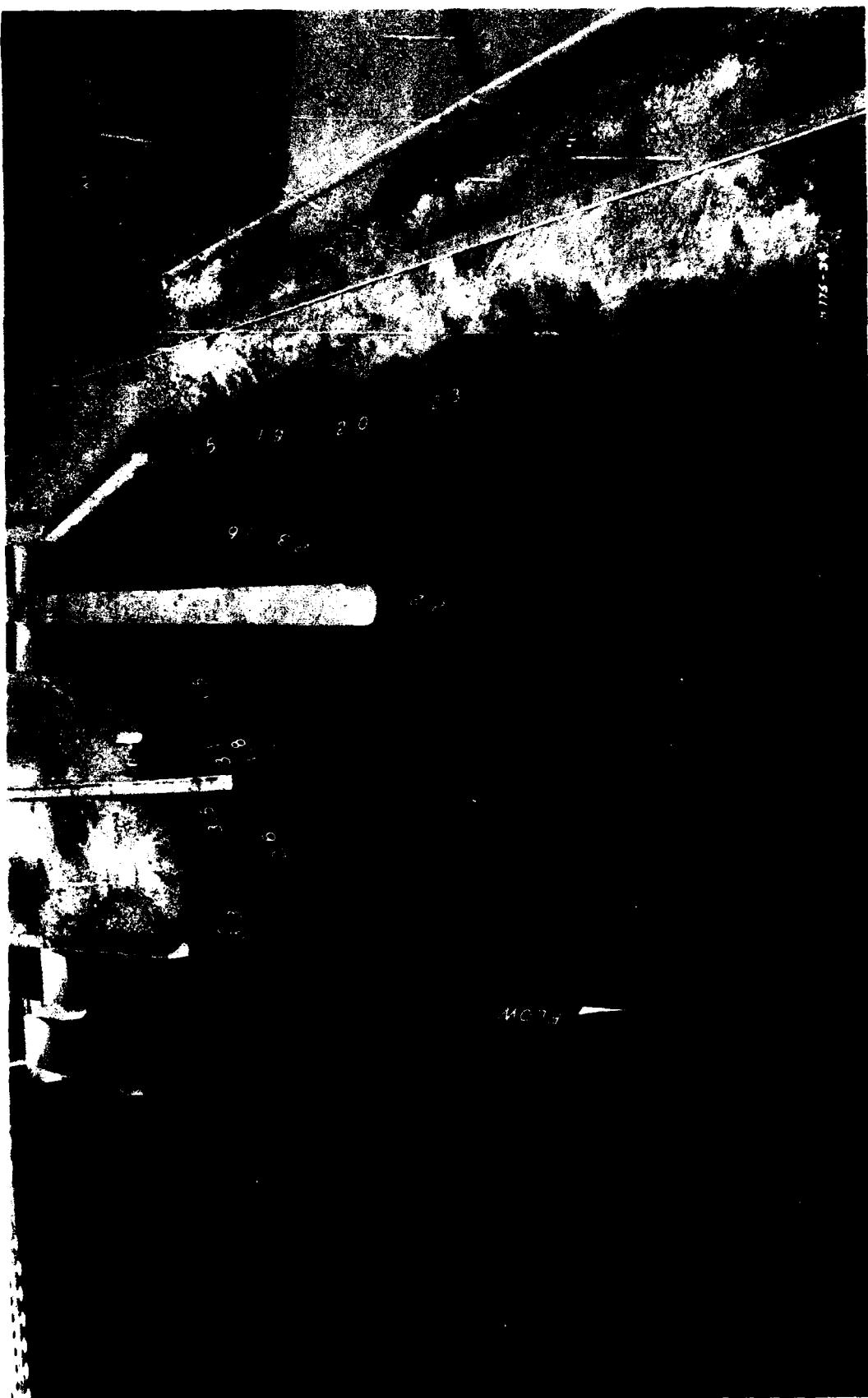


Photo 35. Plan E-3, Scheme 2. No river discharge, upper pool el 538.0, lower pool el 515.0. Current velocities in the lower approach to the locks resulting from emptying of both locks simultaneously in 8 min



Photo 36. Plan E-4, Scheme 6. No river discharge, upper pool el 538.0, lower pool el 515.0. Dye pattern and superimposed arrows indicate direction of bottom currents during lock emptying in 8 min



Photo 37. Plan E-4, Scheme 6. No river discharge, upper pool el 538.0, lower pool el 515.0. Surface currents during lock emptying in 8 min.  
Note eddy in lower approach to existing lock



Photo 38. Plan E-5, Scheme 6. No river discharge, upper pool el 538.0, lower pool el 315.0. Dye showing current pattern developed during lock emptying in 8 min



Photo 39. Plan E-5, Scheme 6. No river discharge, upper pool el 538.0, lower pool el 515.0. Surface currents during lock emptying in 8 min.

Note eddy extending into the approach to the existing locks



Photo 40. Plan E-5, Scheme 6. No river discharge, upper pool el 538.0, lower pool el 515.0. Current velocities obtained with floats submerged to a depth of 9 ft during lock emptying in 8 min

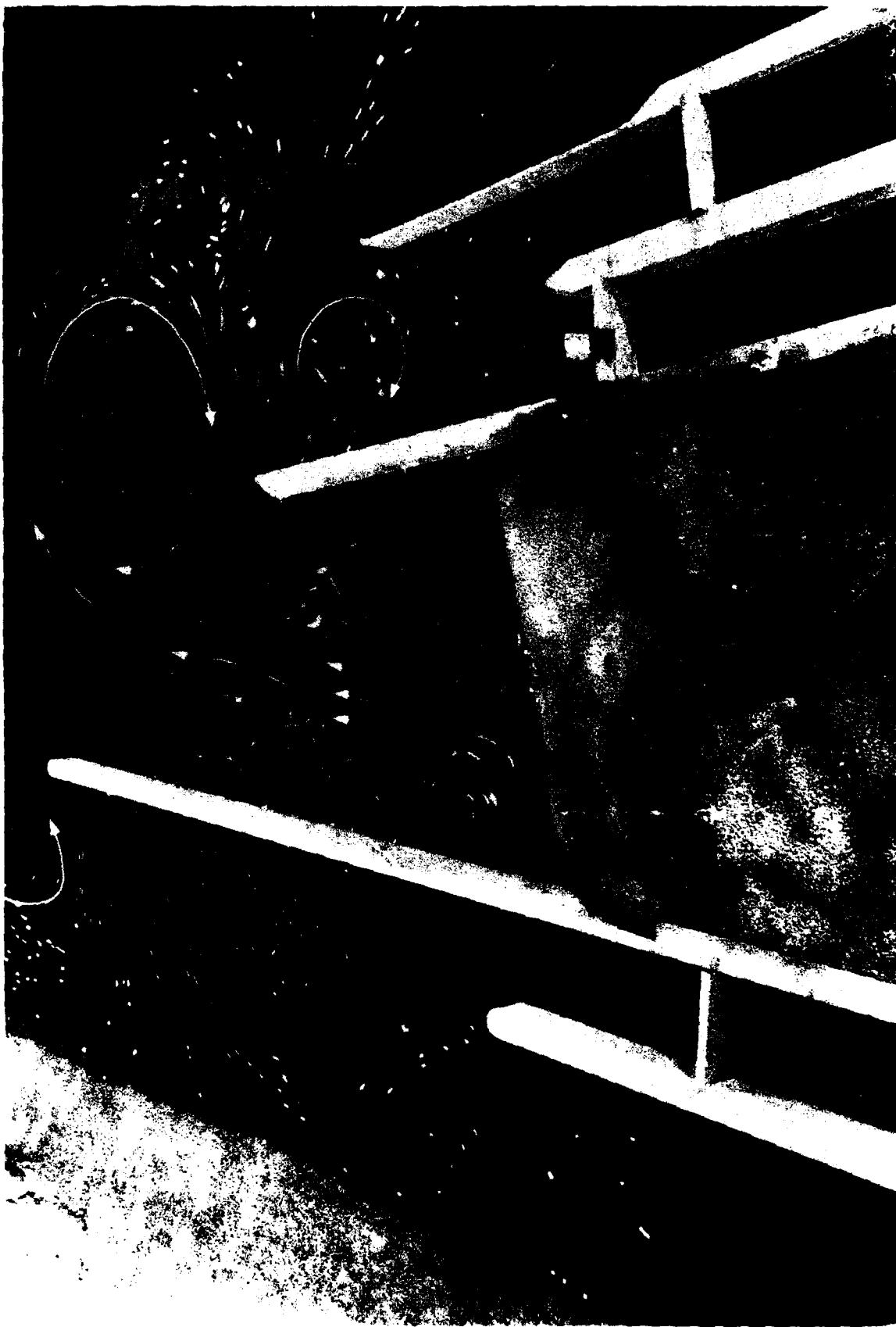


Photo 41. Plan E-7 modified, Scheme 7. No river discharge, upper pool el 538.0, lower pool el 515.0. Surface current and dye pattern during emptying both new locks simultaneously in 8 min. Note eddy in lower approach to existing lock



Photo 42. Plan E-7 modified, Scheme 7. No river discharge, upper pool el 538.0, lower pool el 515.0.  
Current direction and velocities resulting from emptying both the new locks simultaneously in 8 min



Photo 43. Plan E-7 modified, Scheme 8. No river discharge, upper pool el 538.0, lower pool el 515.0. Surface current and dye patterns during emptying the 600-ft lock in 8 min. Note the concentration near the end of the guide wall



Photo 44. Plan E-7 modified, Scheme 8. No river discharge, upper pool el 538.0, lower pool el 515.0. Current direction and velocities in the lock approach resulting from emptying the 600-ft lock in 8 min

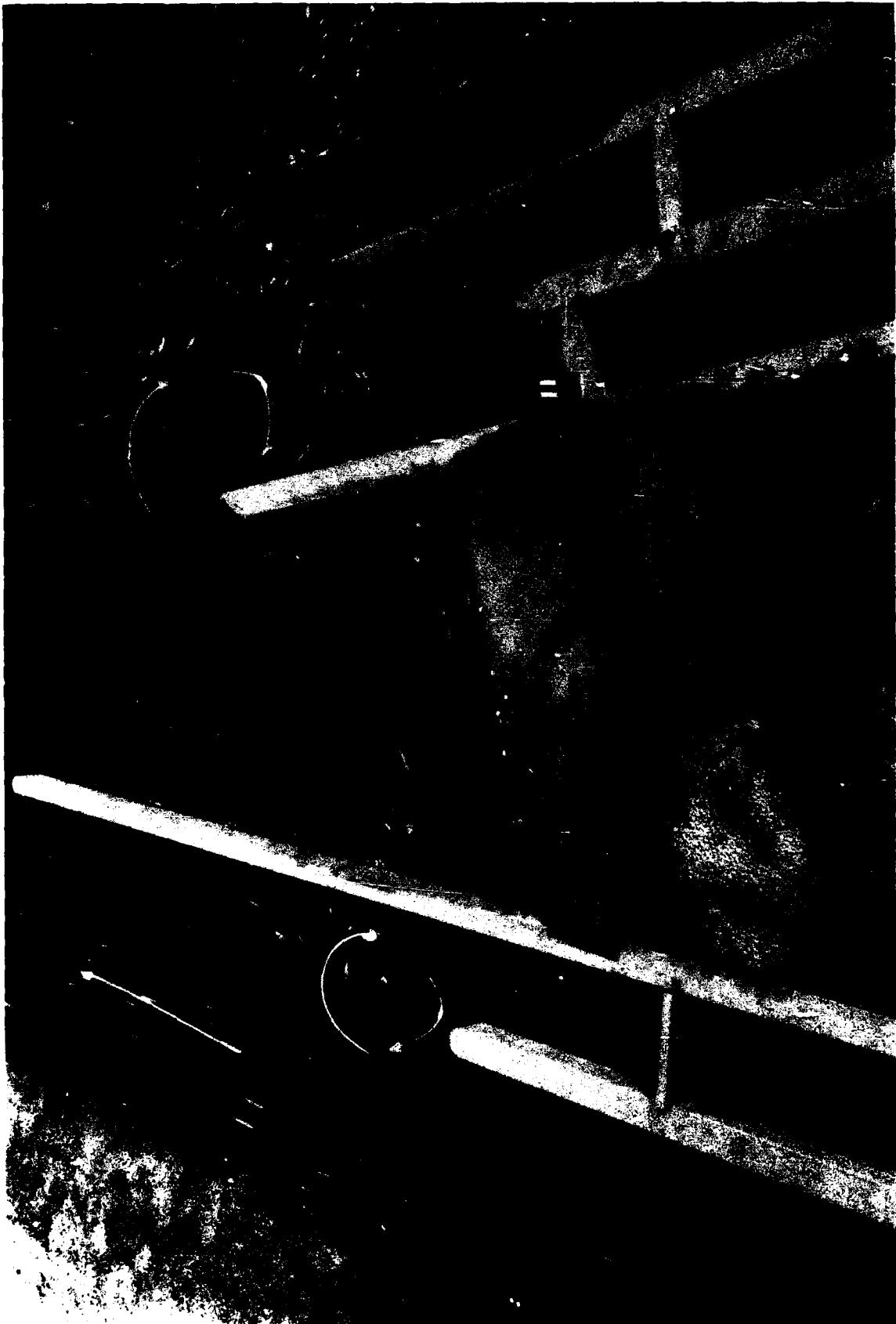


Photo 45. Plan E-7 modified, Scheme 9. No river discharge, upper pool el 538.0, lower pool el 515.0. Surface current and dye patterns during emptying the 600-ft lock in 8 min. Note eddy in approach to existing locks

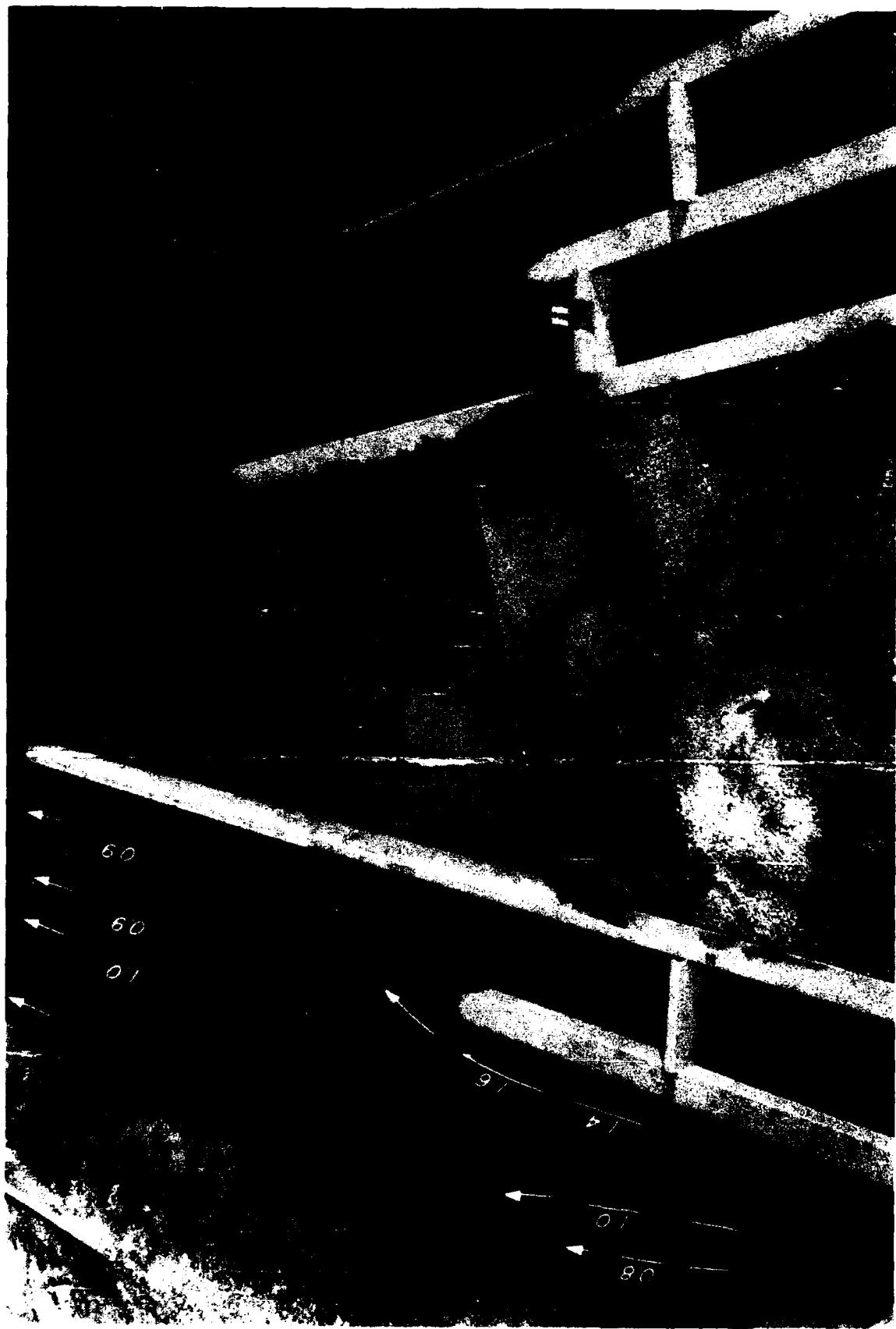


Photo 46. Plan E-7 modified, Scheme 9. No river discharge, upper pool el 538.0, lower pool el 515.0. Current direction and velocities in the lock approach resulting from emptying the 600-ft lock in 8 min

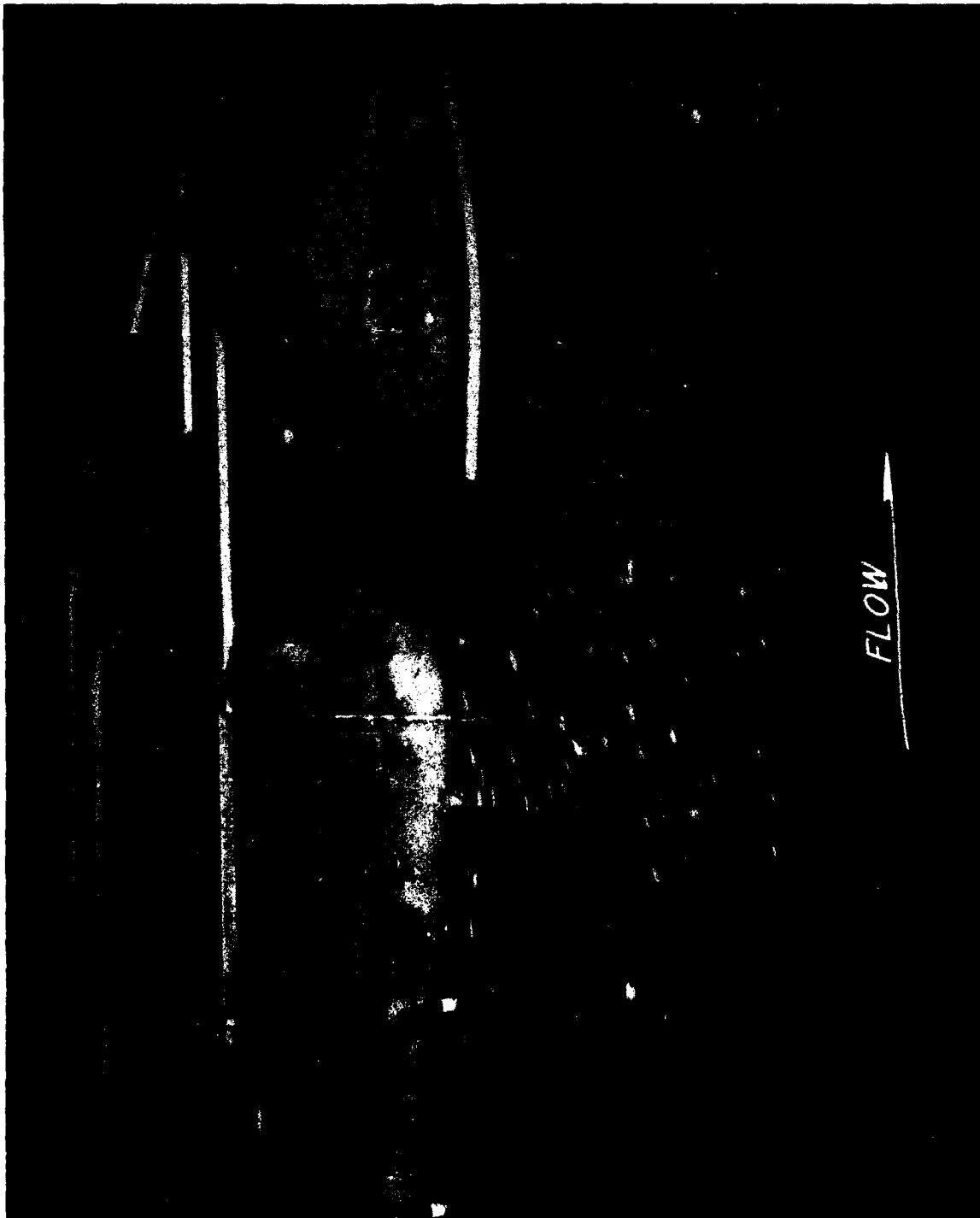


Photo 47. Plan E-10 modified, Scheme 9. Discharge 16,000 cfs, upper pool el 538.0, lower pool el 515.0. Confetti showing surface current in the approach to the filling intakes resulting from filling both new locks simultaneously in 8 min

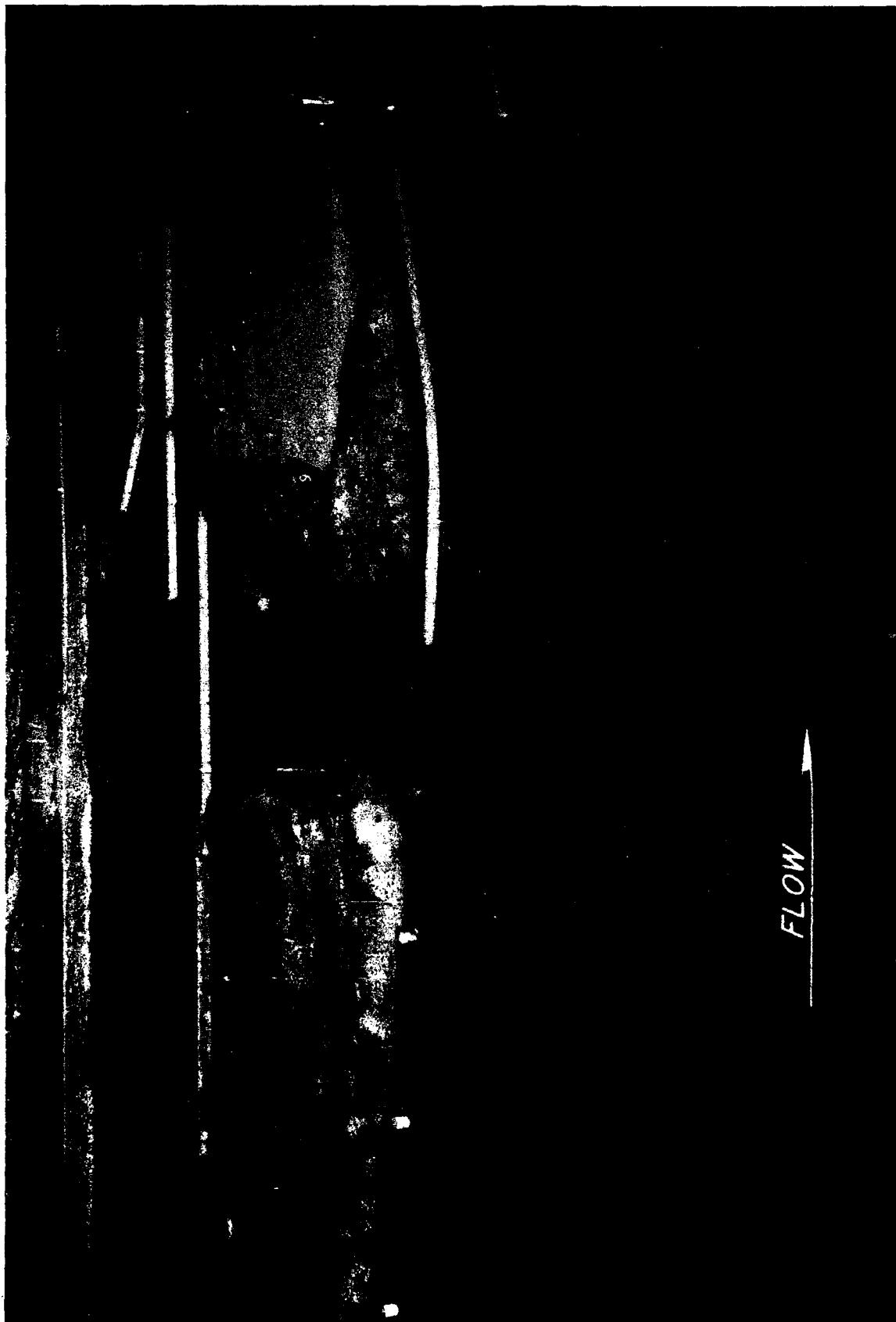


Photo 48. Plan E-10 modified, Scheme 9. Discharge 217,000 cfs, upper pool el 538.0, lower pool el 537.0. Confetti showing the absence of surface current in the approach to the filling intakes resulting from continuous filling of both new locks

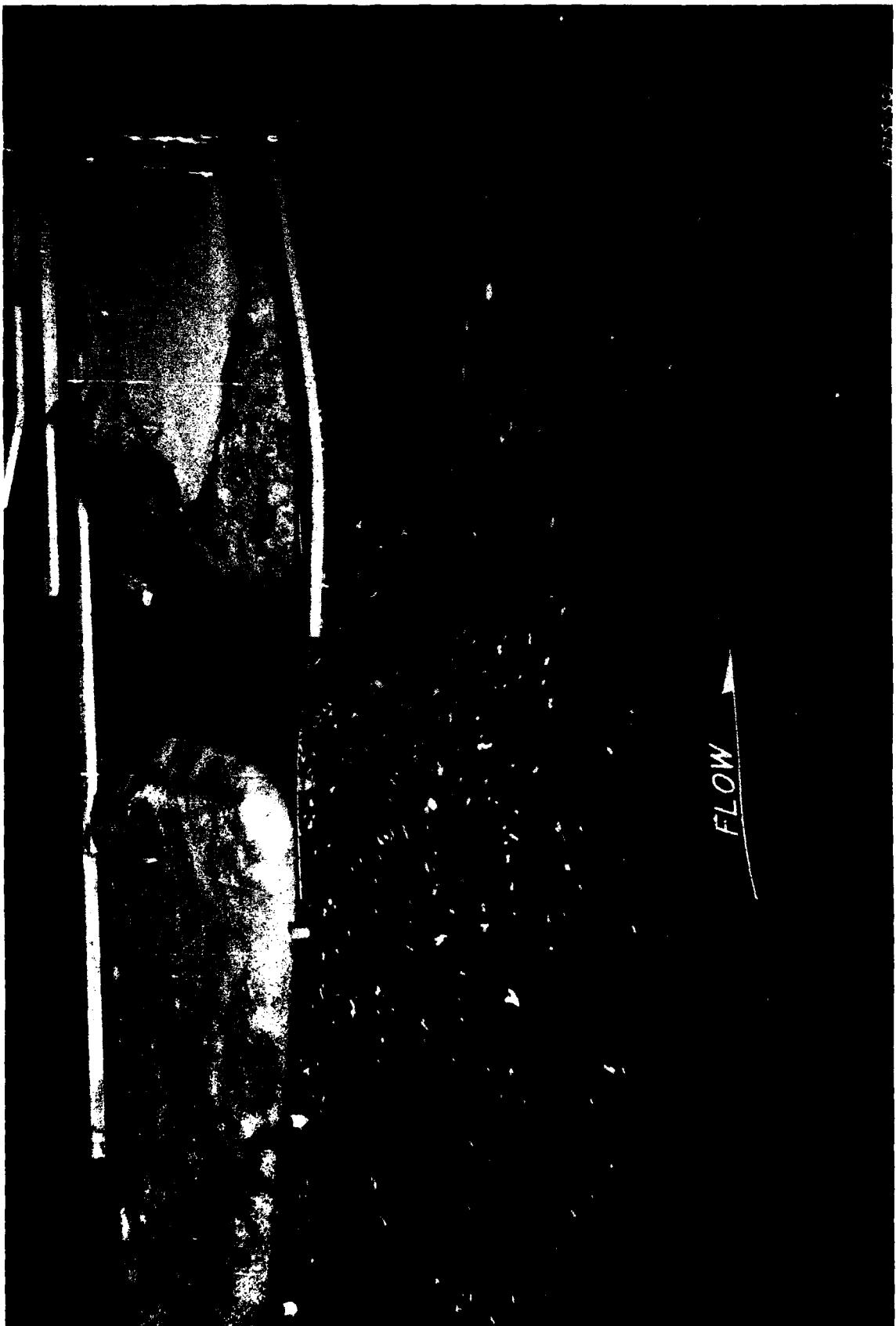


Photo 49. Plan E-10 modified, Scheme 9. Discharge 16,000 cfs, upper pool el 538.0, lower pool el 515.0. Confetti showing effects of log boom on surface current in the approach to the filling intakes resulting from filling both new locks simultaneously in 8 min

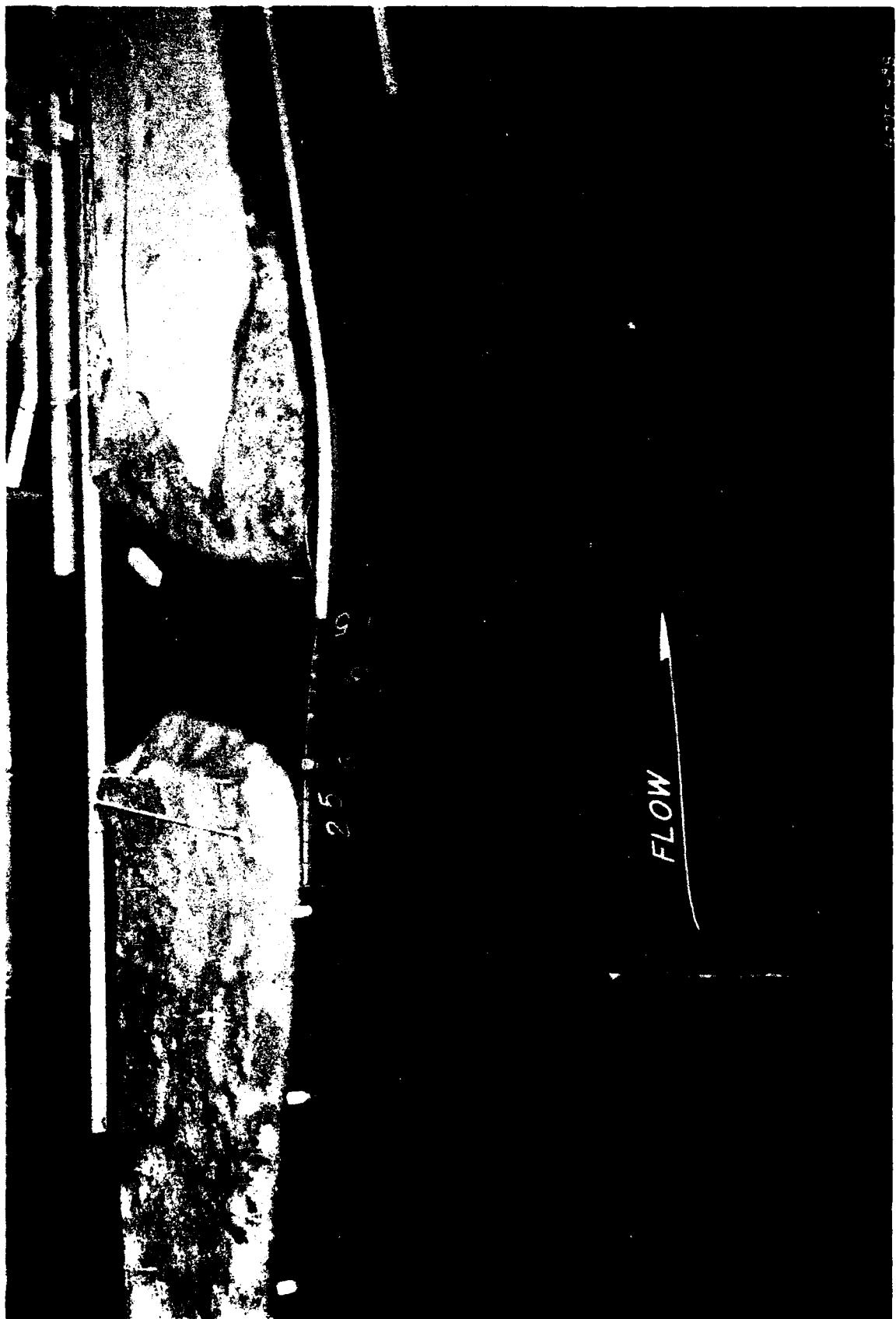


Photo 50. Plan E-10 modified, Scheme 9. Discharge 16,000 cfs, upper pool el 538.0, lower pool el 515.0. Current velocities approaching the log boom resulting from filling both new locks simultaneously in 8 min

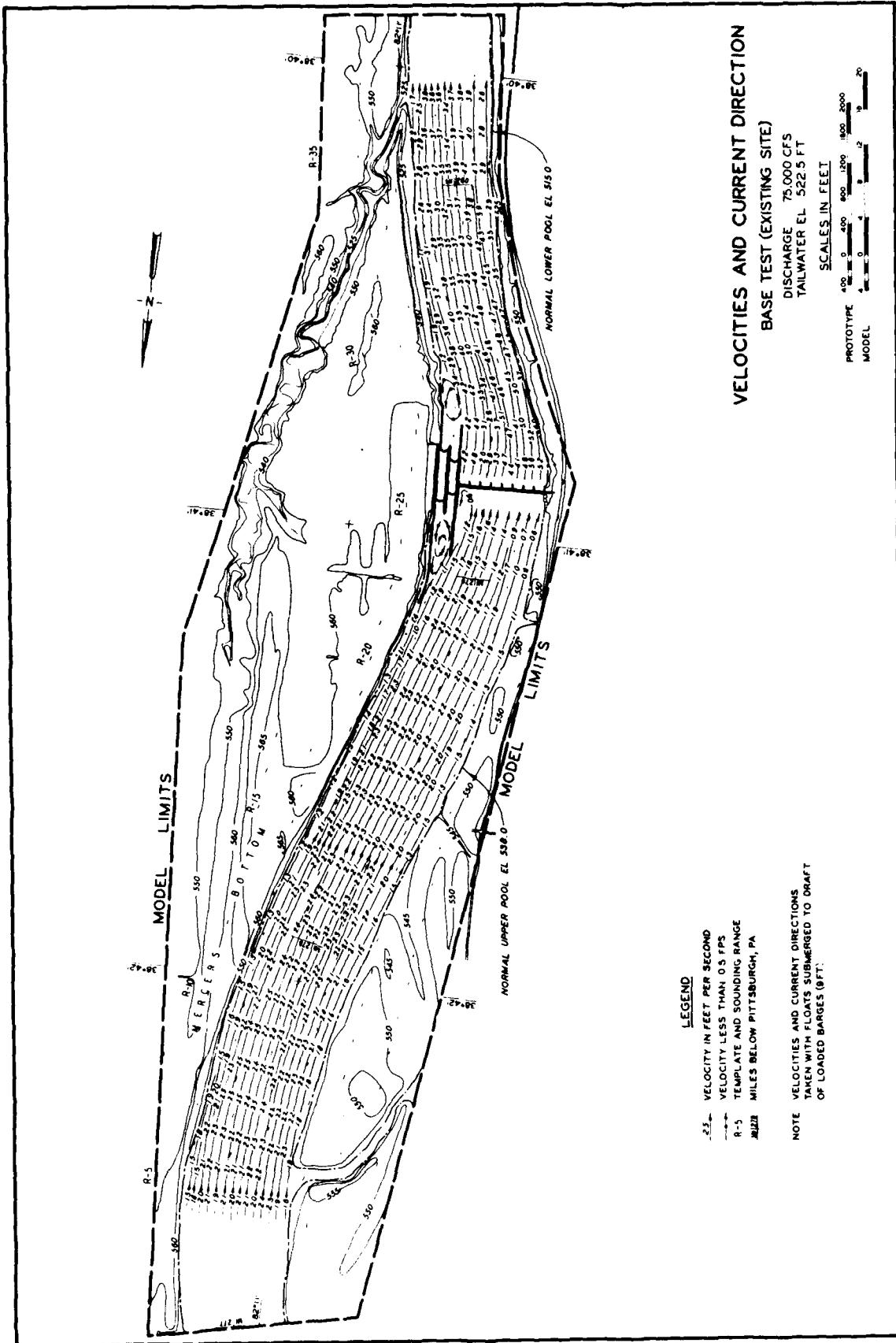


PLATE 1

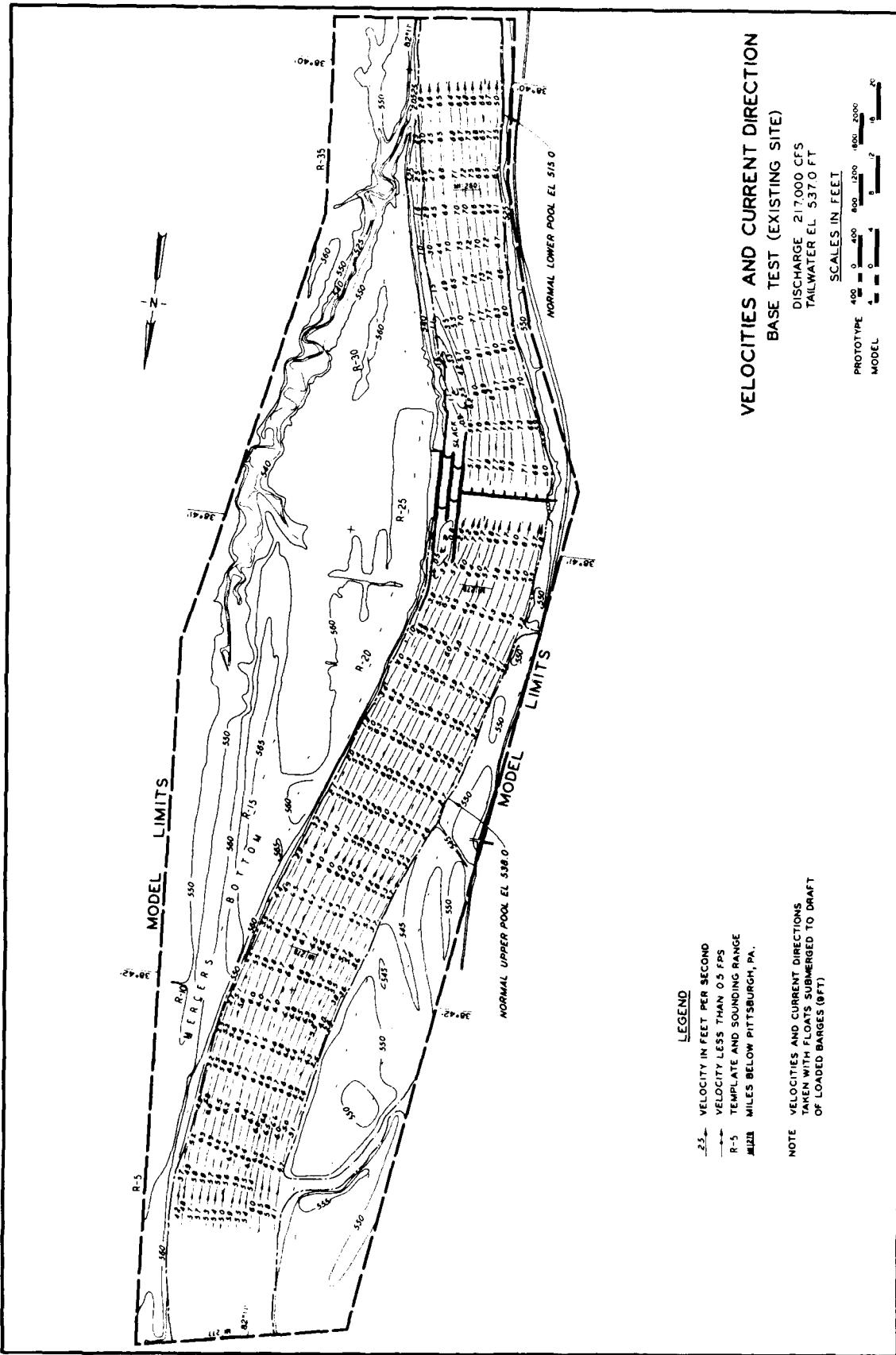


PLATE 2

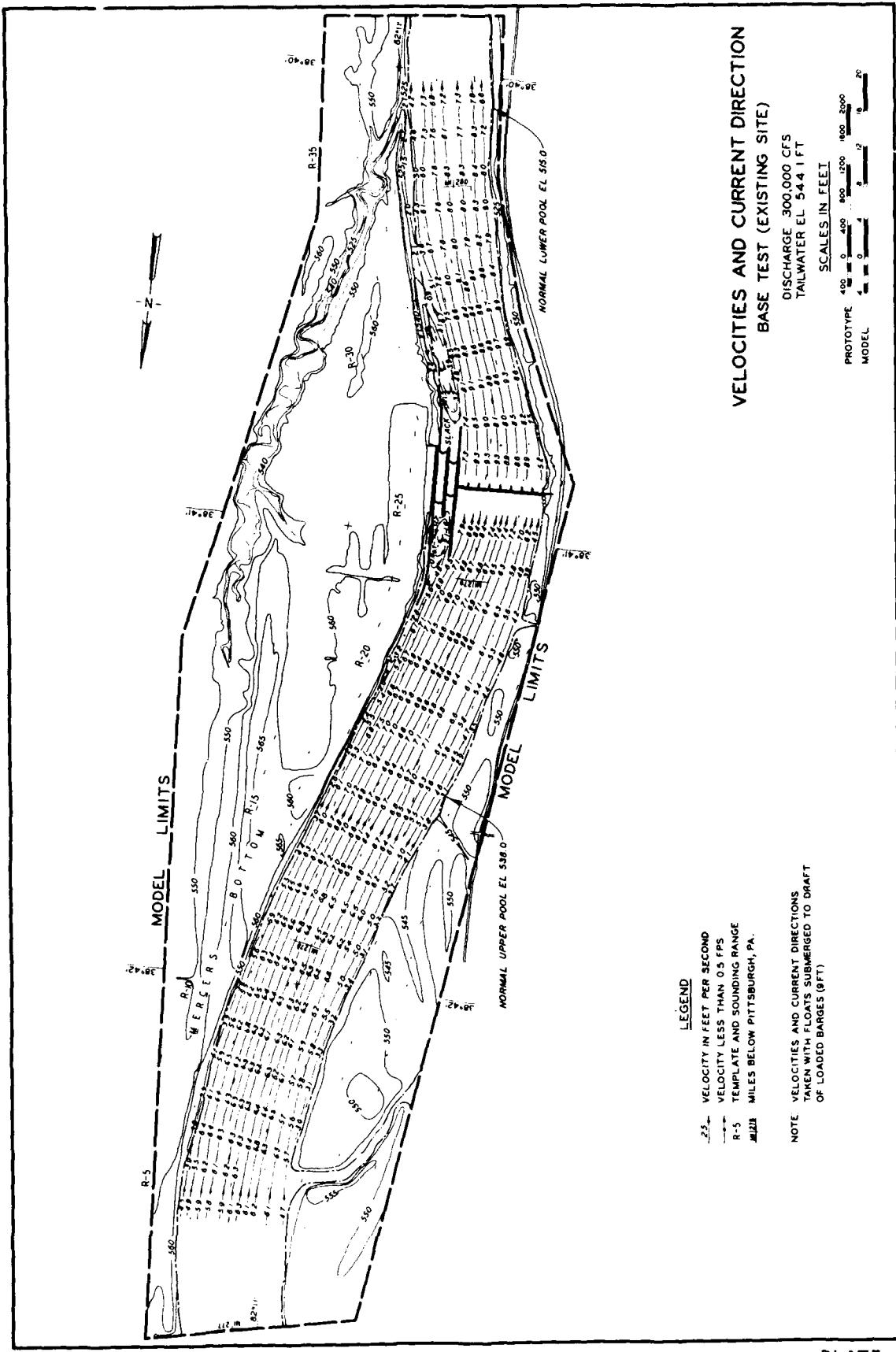


PLATE 3

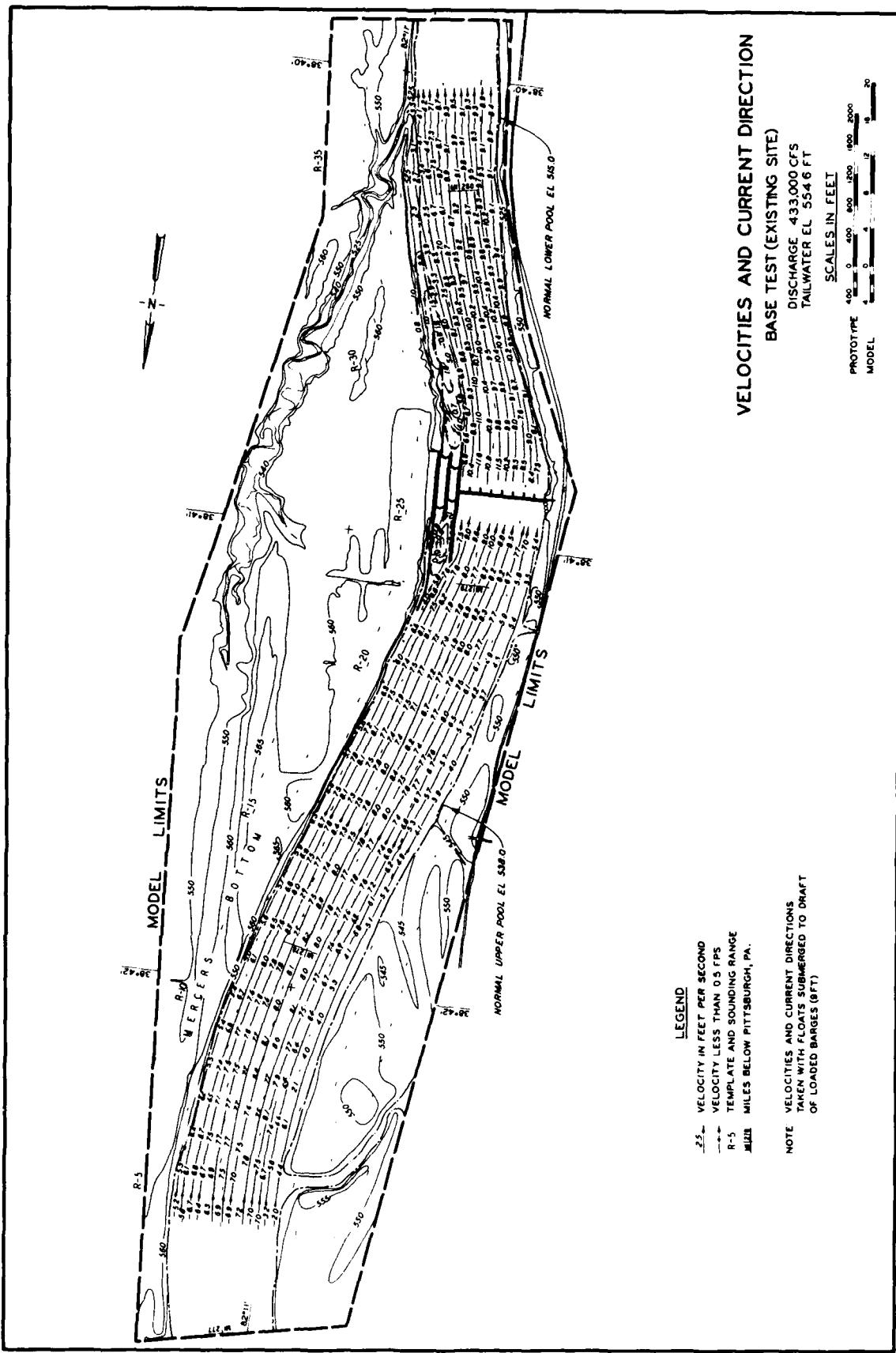
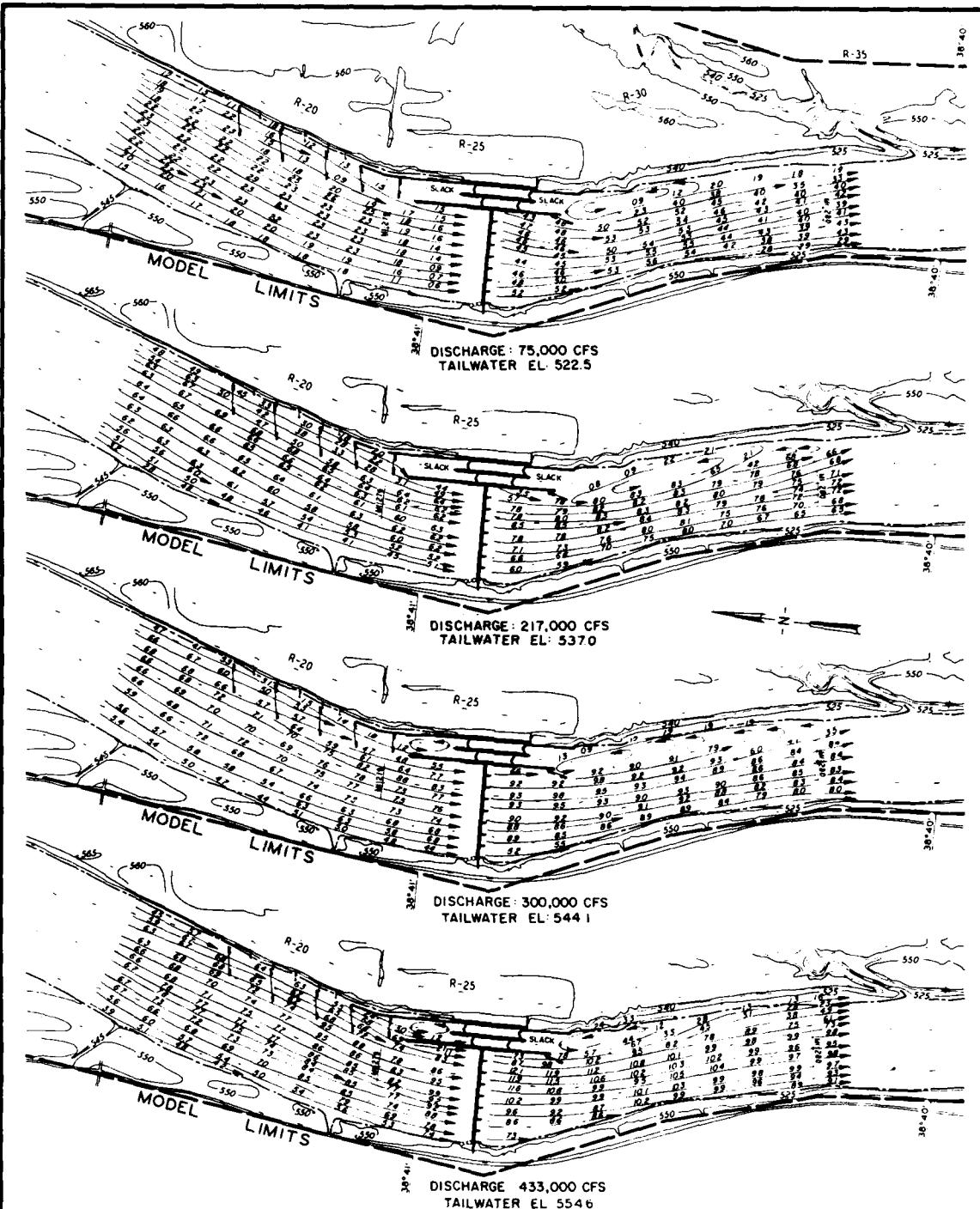


PLATE 4



### VELOCITIES AND CURRENT DIRECTION PLAN E

DISCHARGES : 75,000 ; 217,000 ;  
300,000 AND 433,000 CFS

PROTOTYPE    400    0    400    800    1200    1600    2000  
MODEL        4       0       4       8       12       16       20

SCALES IN FEET

PLATE 5

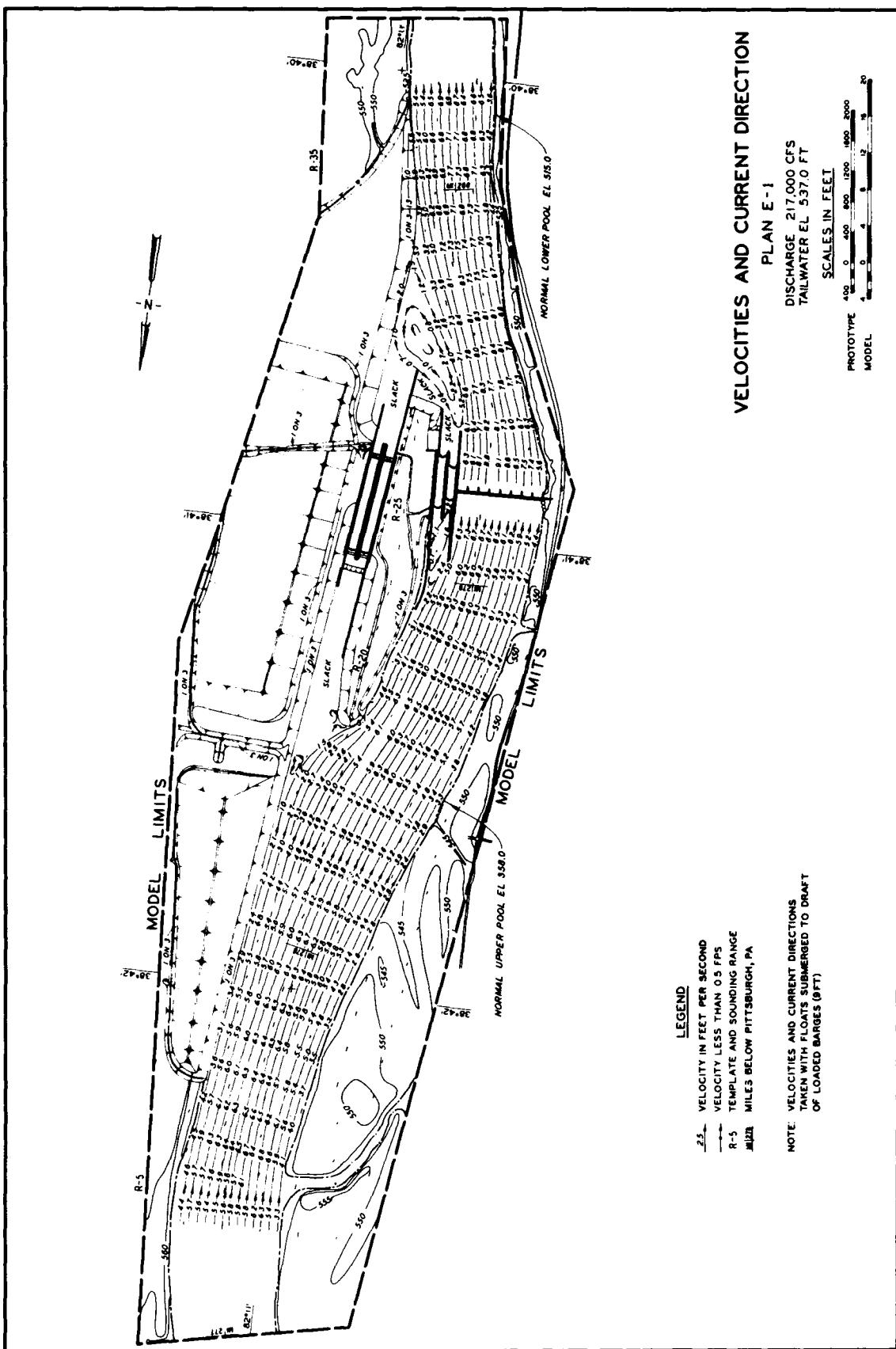


PLATE 6

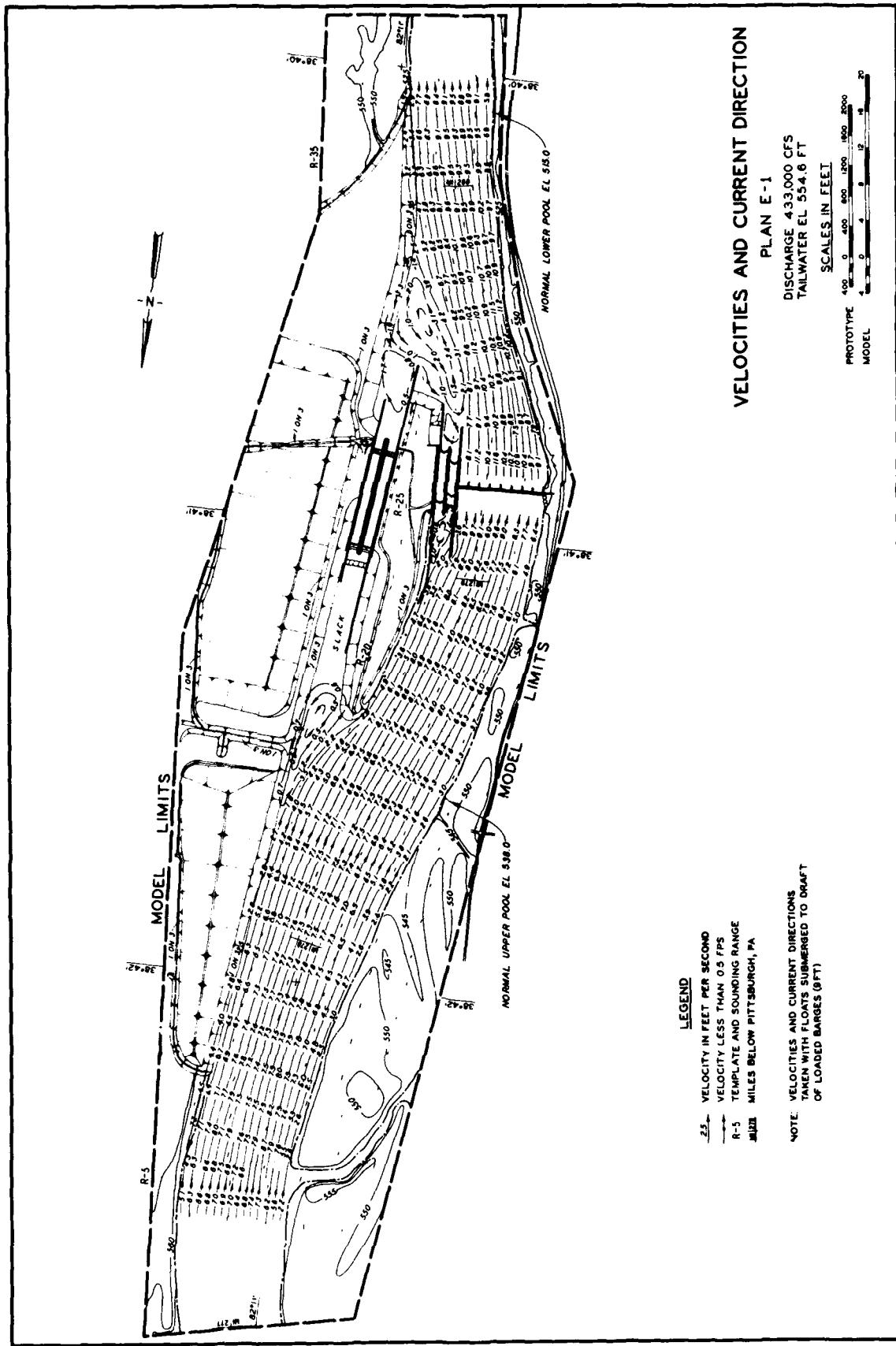


PLATE 7

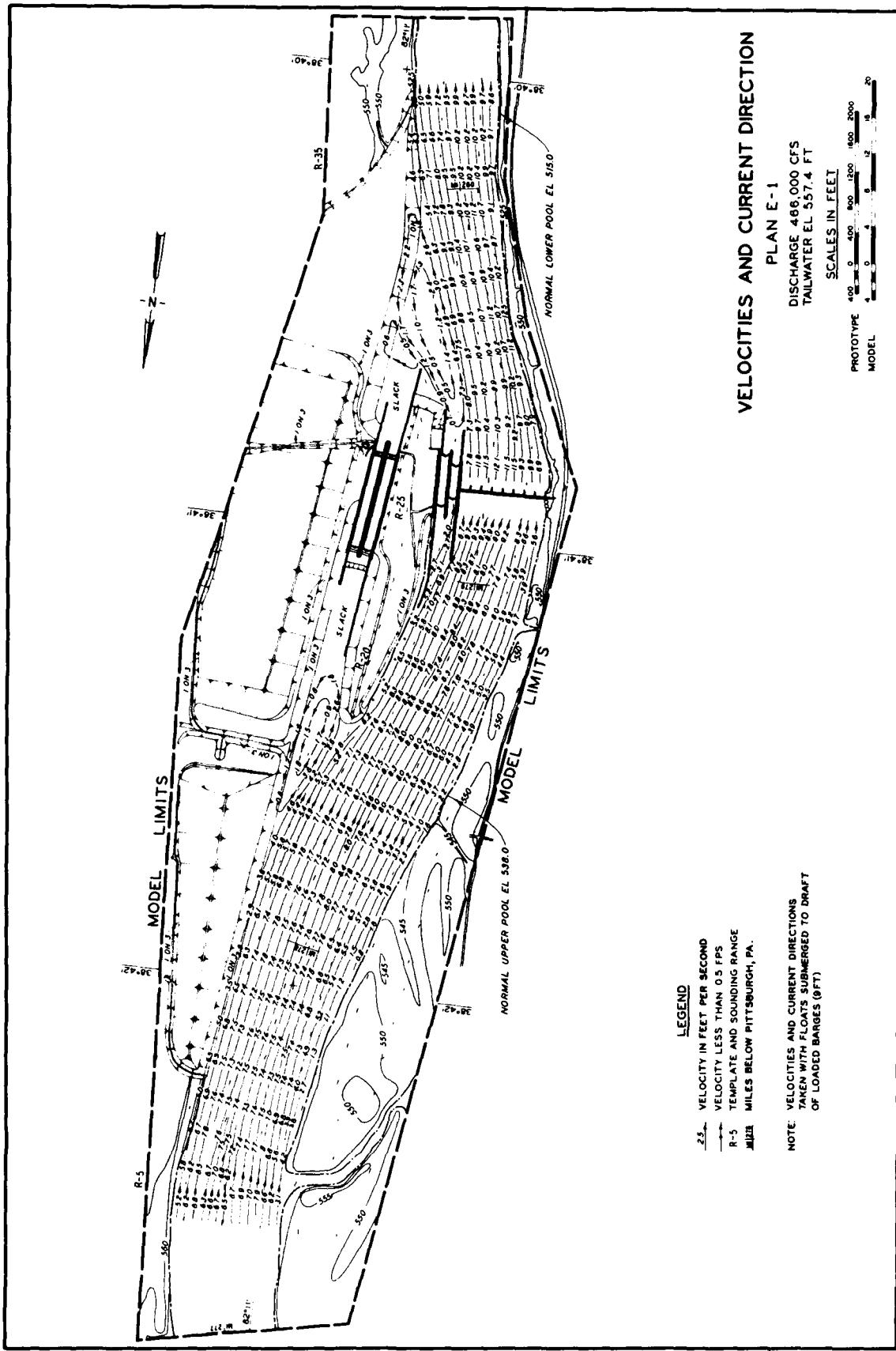


PLATE 8

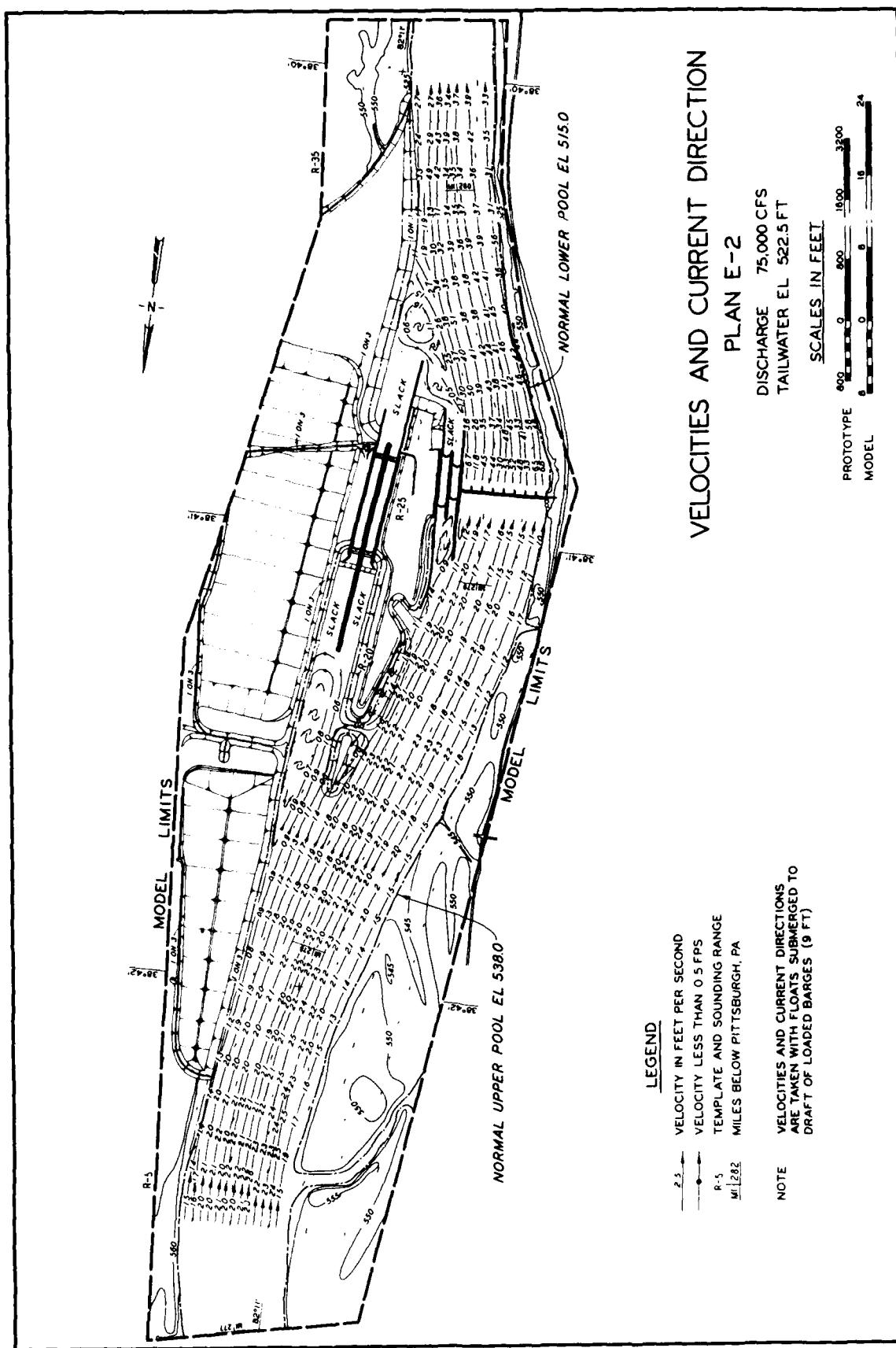
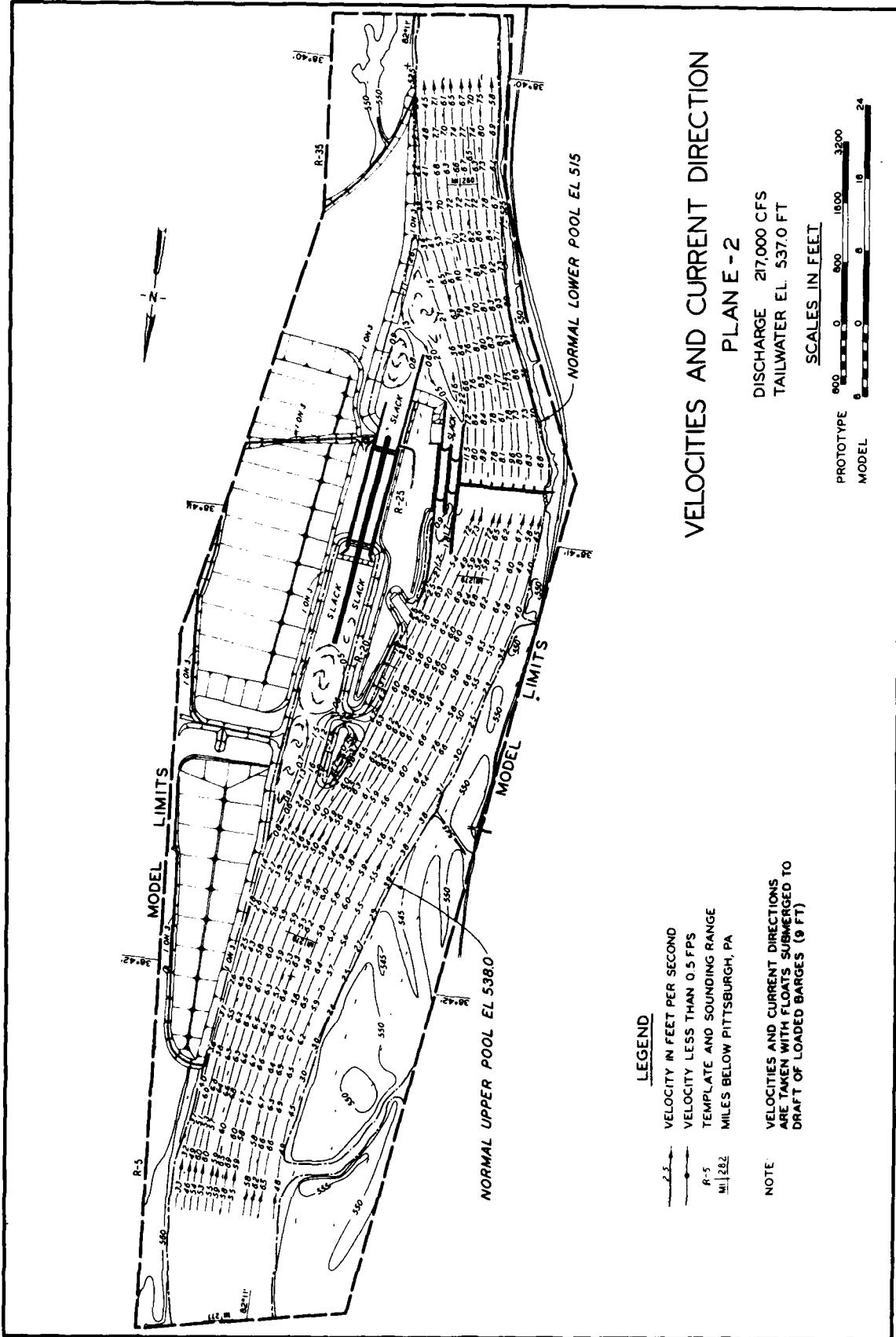


PLATE 9



**VELOCITIES AND CURRENT DIRECTION**

**PLAN E-2**

DISCHARGE 466,000 CFS  
TAILWATER EL 557.4 FT

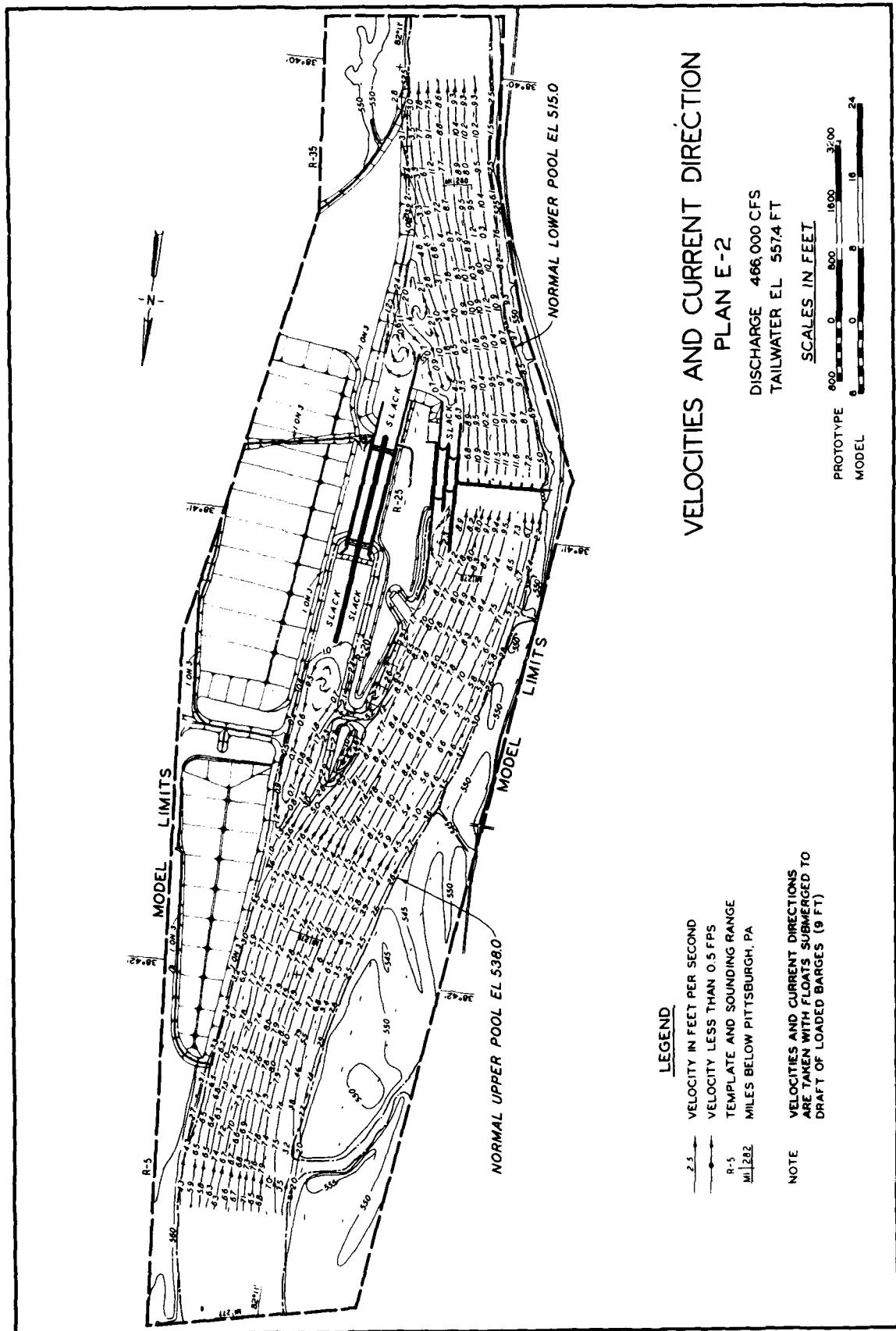
**SCALES IN FEET**

PROTOTYPE 800 0 1600 3200  
MODEL 0 0 8 24

**LEGEND**

- Velocity in feet per second
- Velocity less than 0.5 f/s
- Template and sounding range
- R-5 Miles below Pittsburgh, PA

NOTE  
VELOCITIES AND CURRENT DIRECTIONS  
ARE TAKEN WITH FLOATS SUBMERGED TO  
DRAFT OF LOADED BARGES (9 FT)



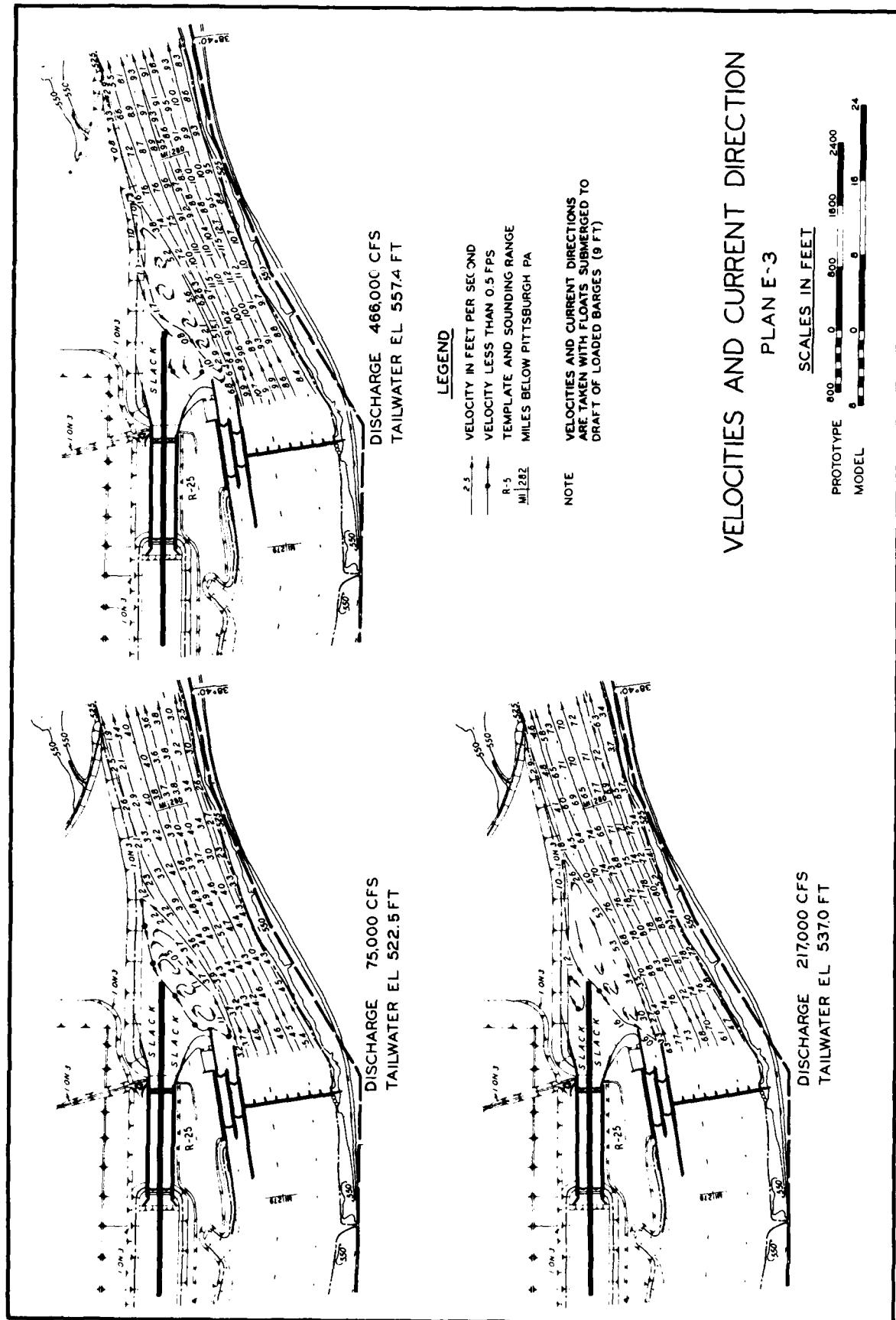


PLATE 12

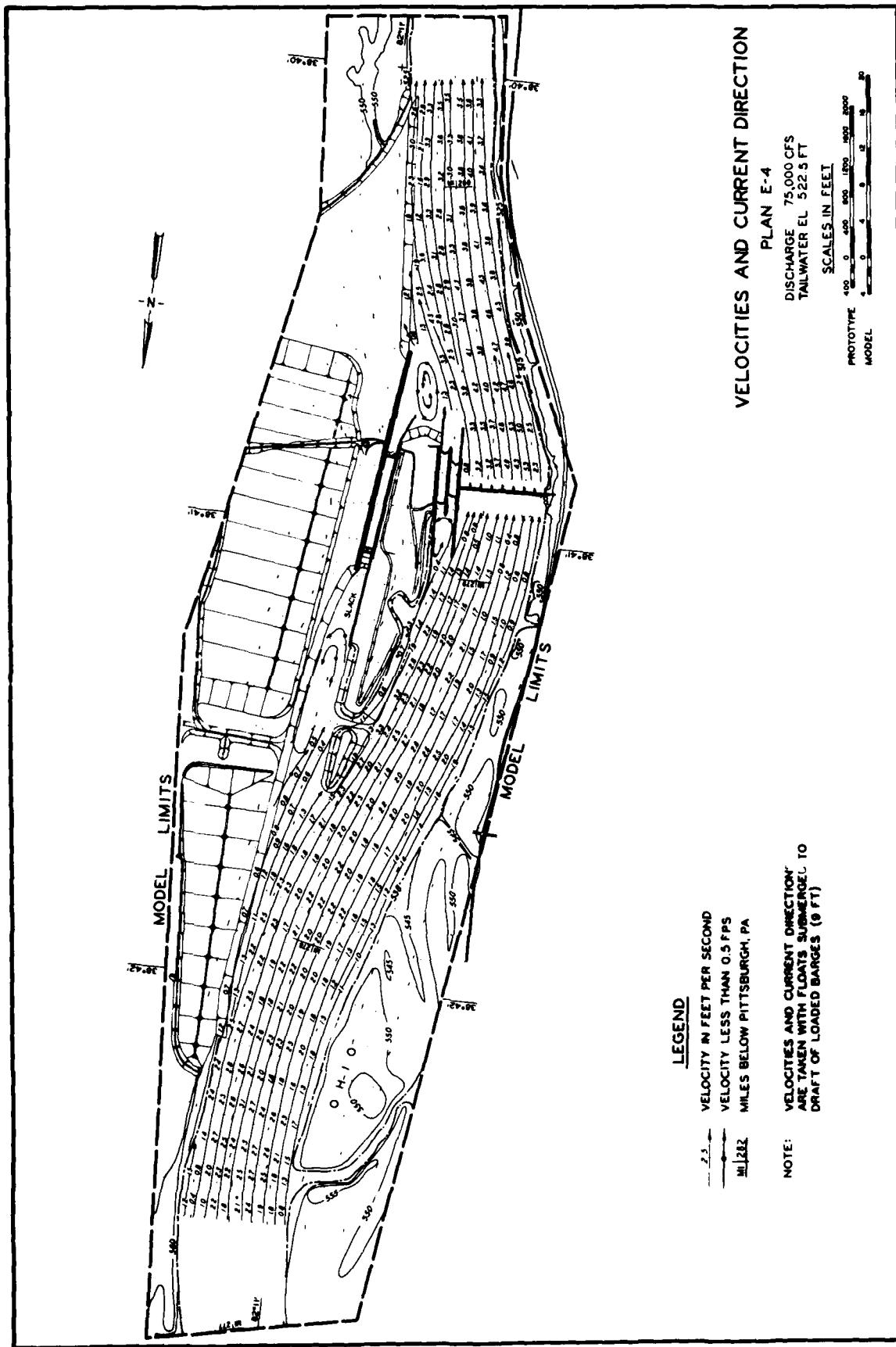


PLATE 13

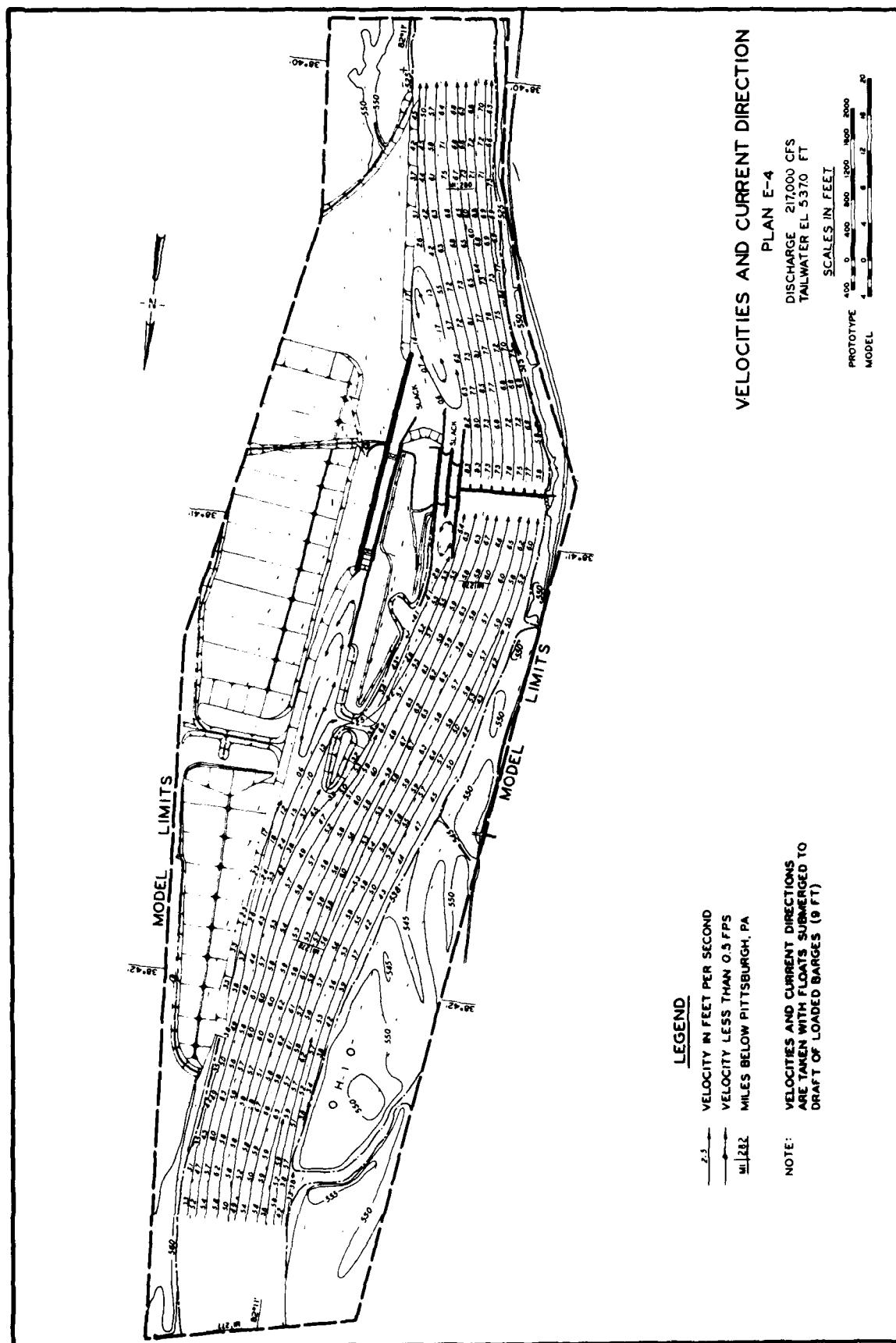
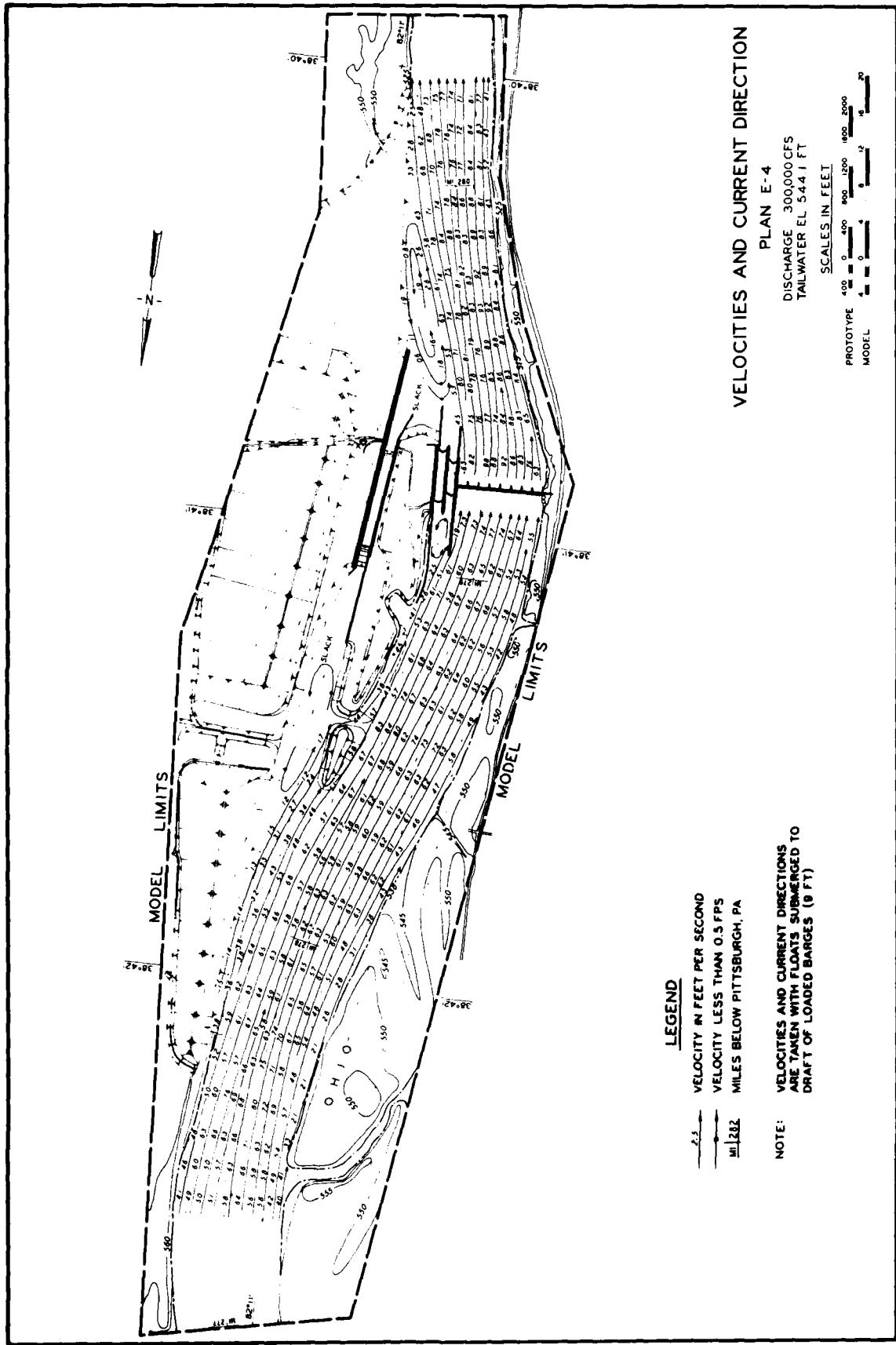


PLATE 14



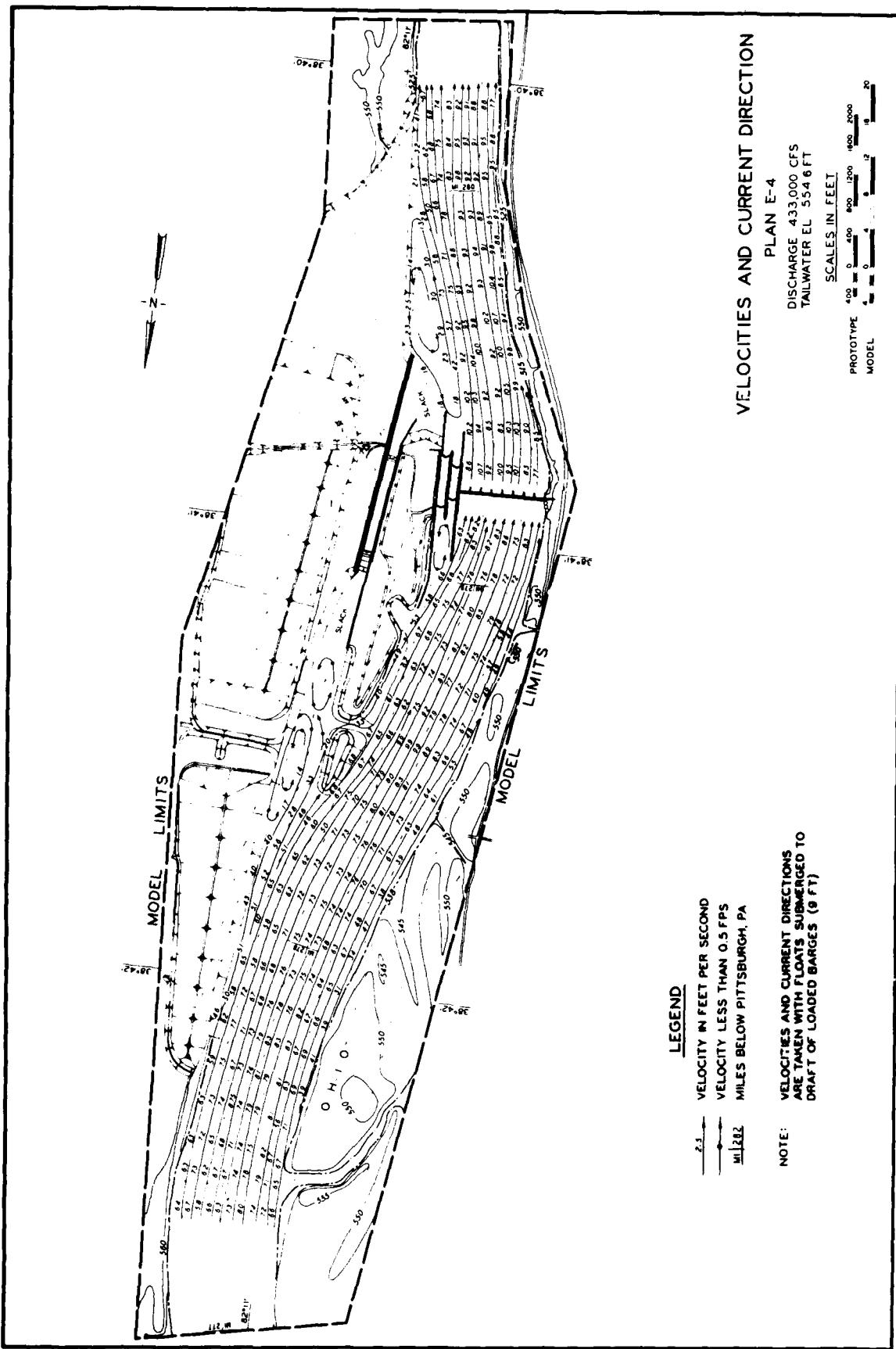
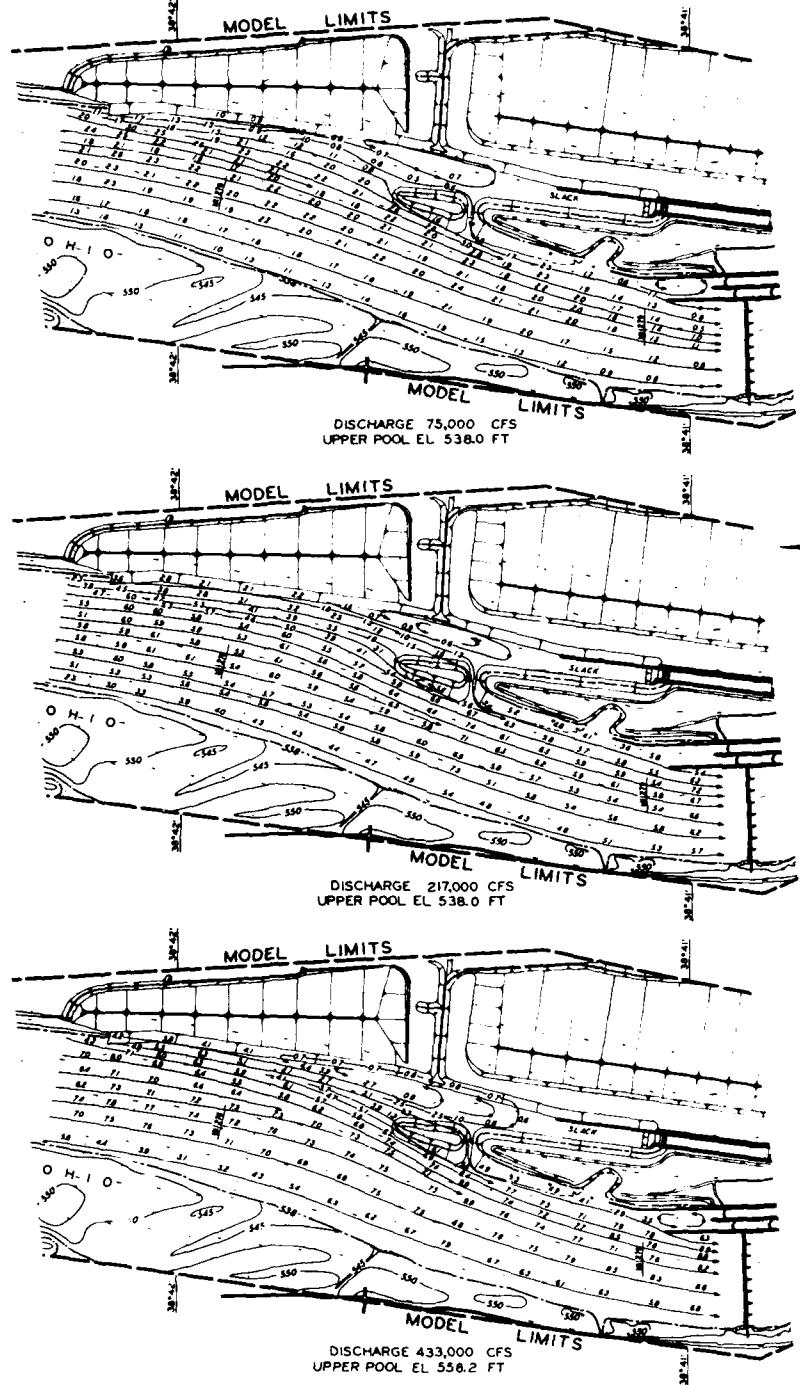


PLATE 16



#### LEGEND

- Velocity in feet per second
- Velocity less than 0.5 FPS
- MILES BELOW PITTSBURGH, PA

NOTE: VELOCITIES AND CURRENT DIRECTIONS  
ARE TAKEN WITH FLOATS SUBMERGED TO  
DRAFT OF LOADED BARGES (9 FT)

#### VELOCITIES AND CURRENT DIRECTIONS

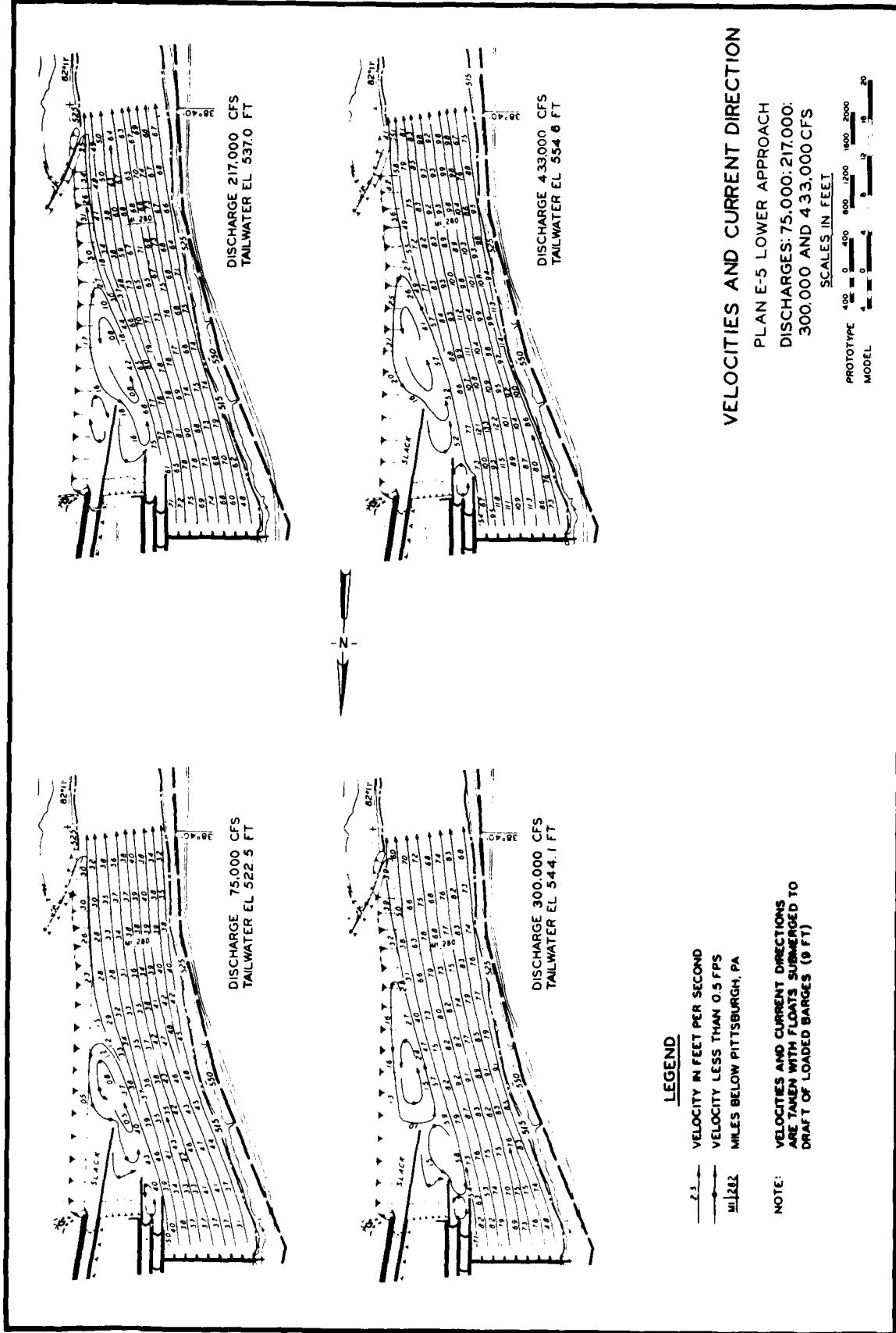
PLAN E-5 UPPER APPROACH

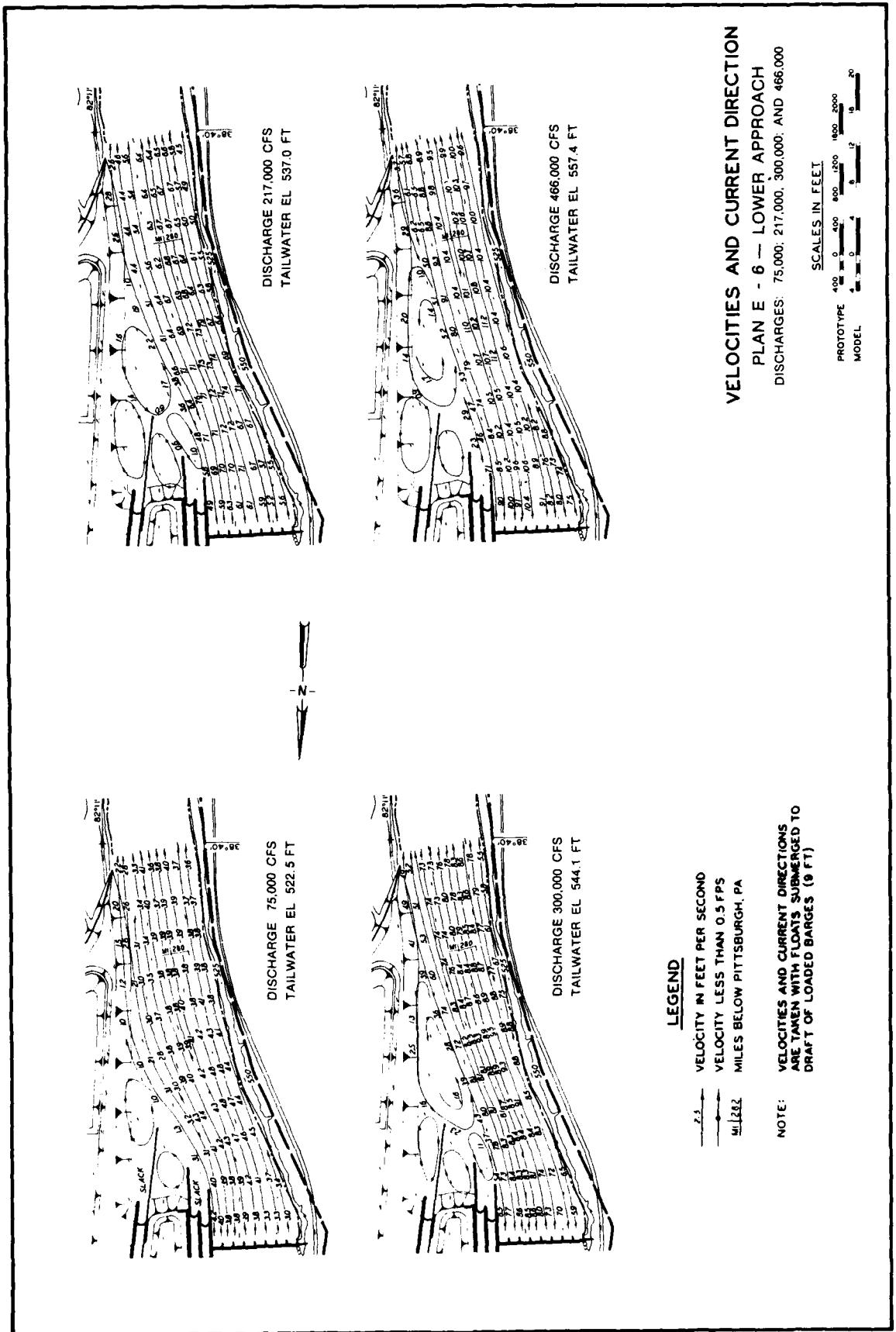
DISCHARGES: 75,000,  
217,000, AND 433,000 CFS

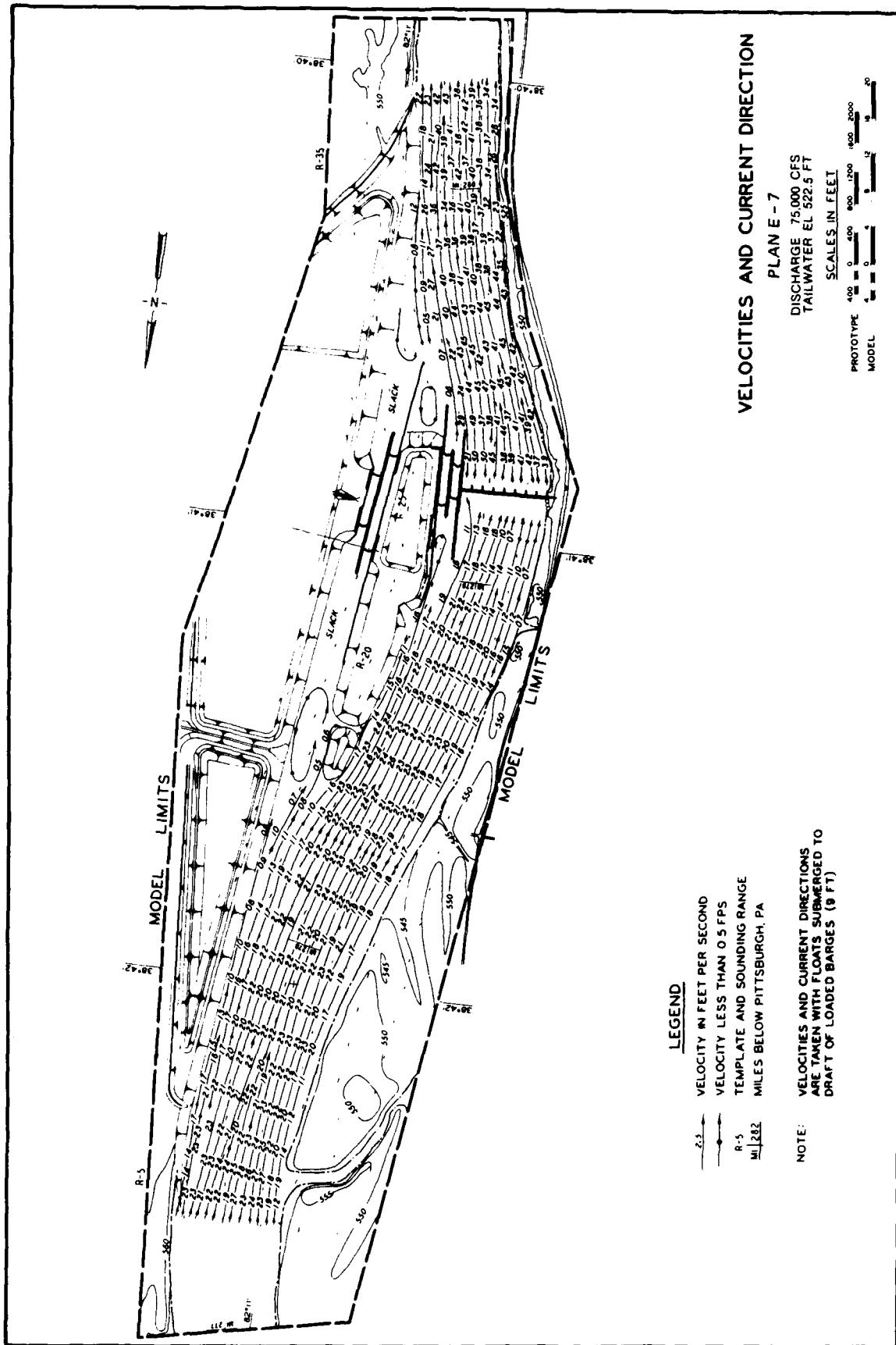
SCALES IN FEET

PROTOTYPE	400	0	400	800	1200	1600	2000
MODEL	4	0	4	8	12	16	20

PLATE 18







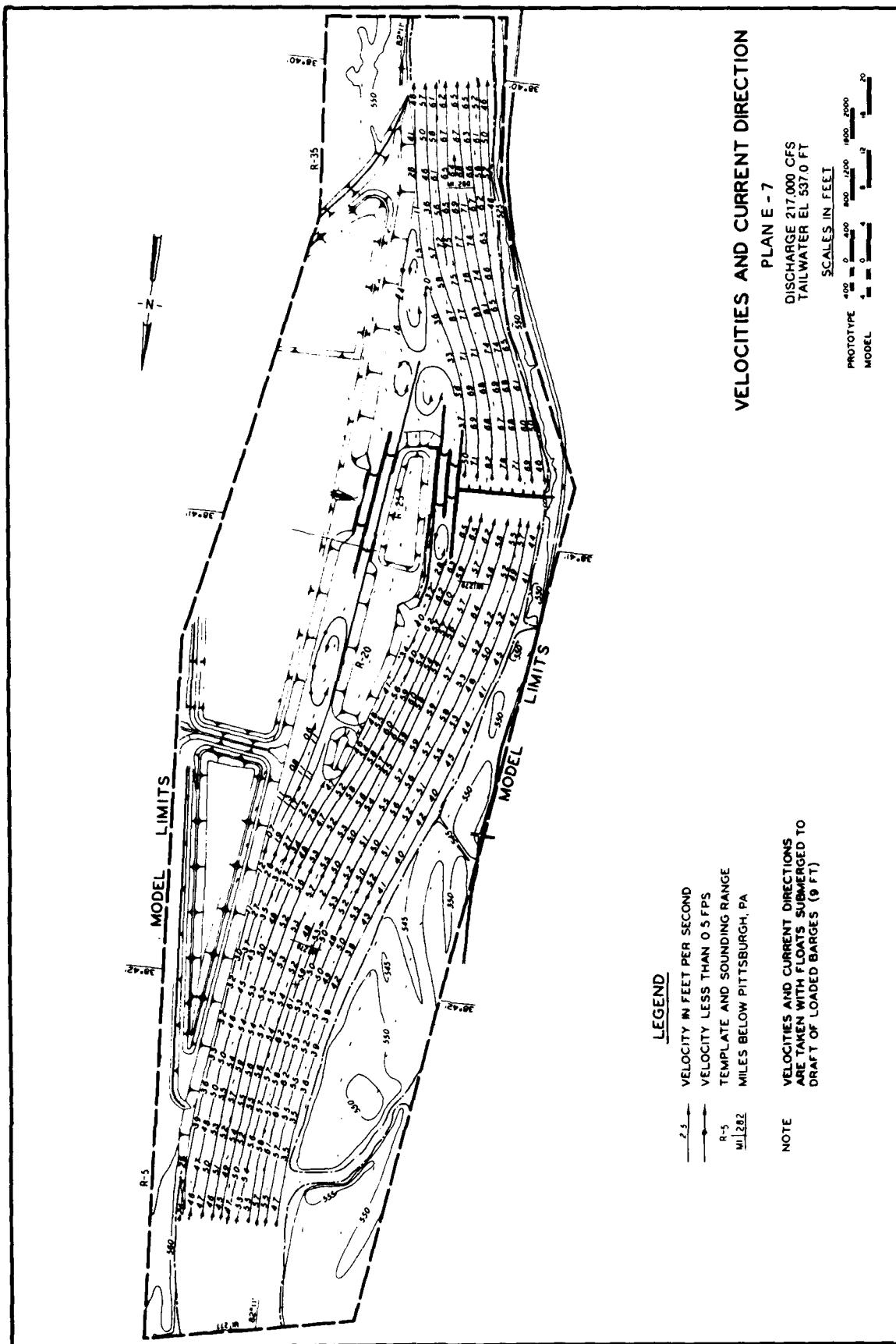


PLATE 21

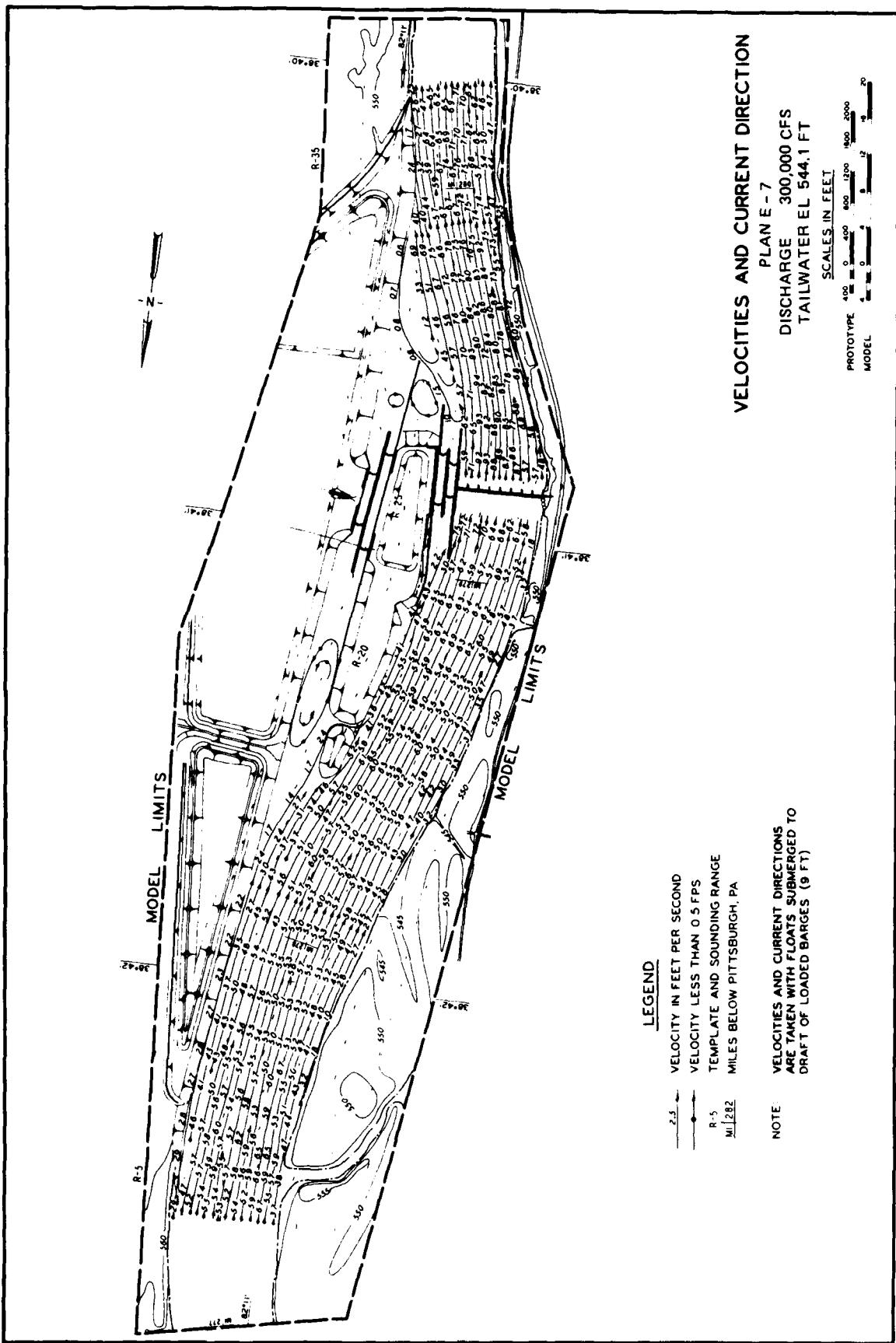


PLATE 22

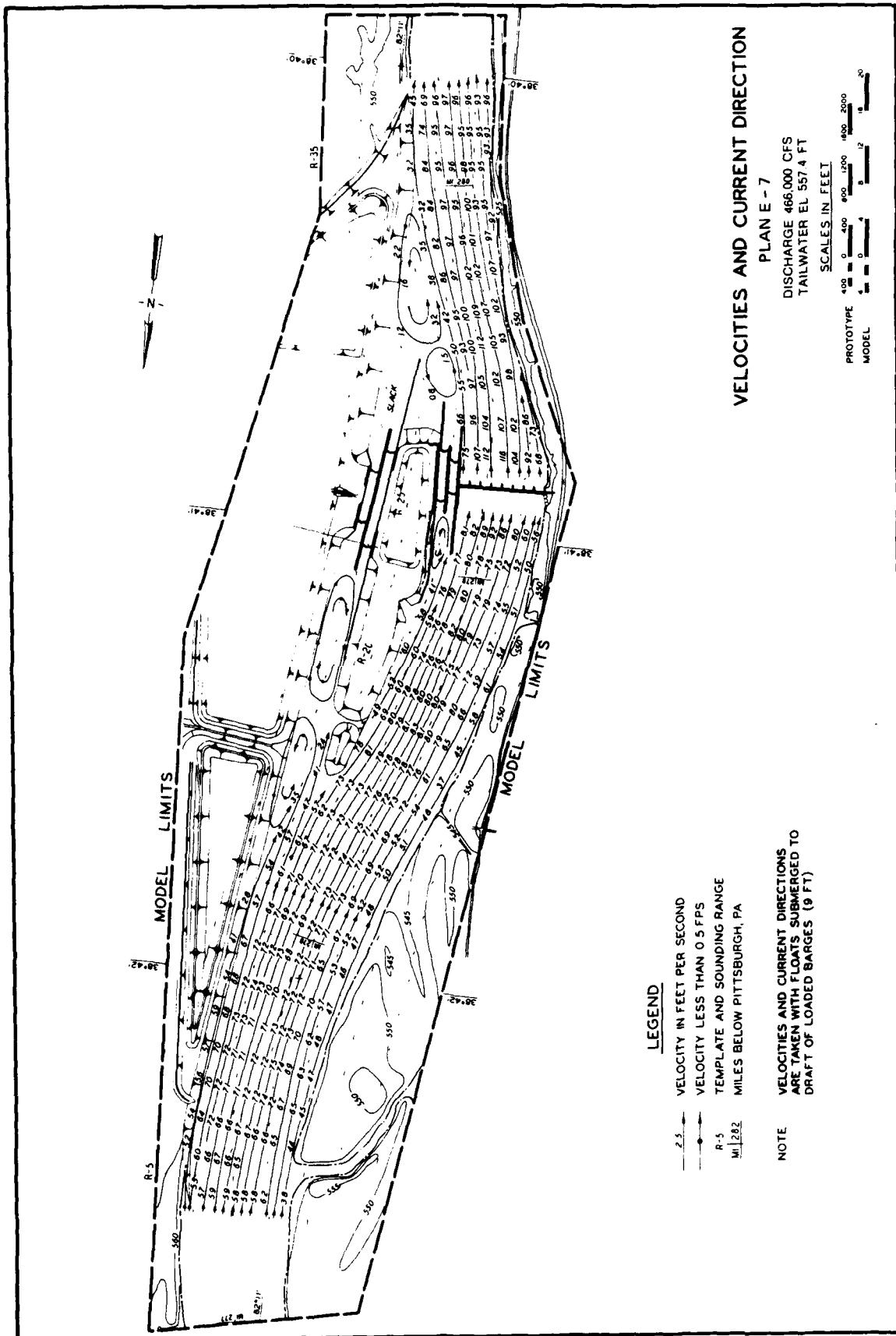
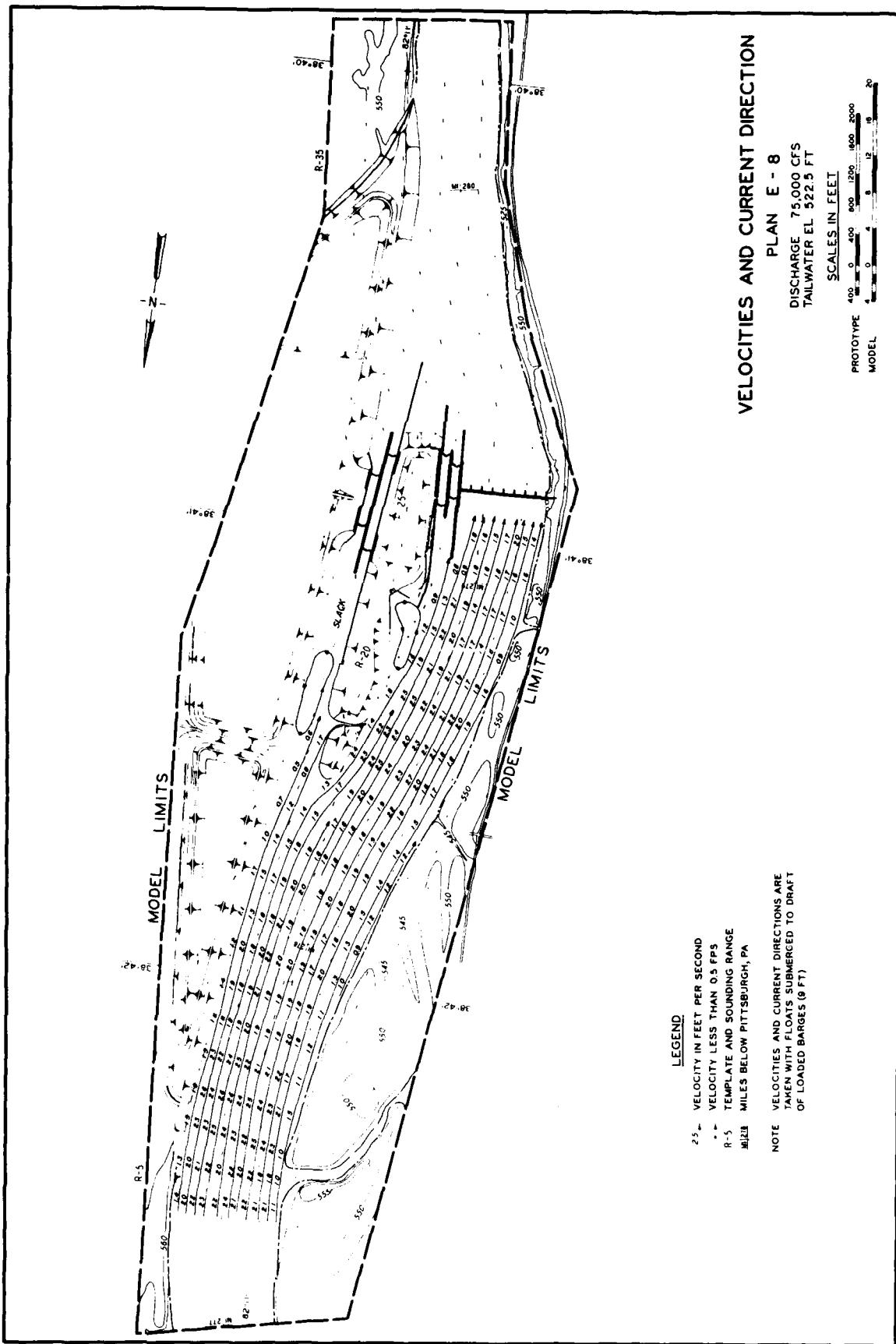


PLATE 23



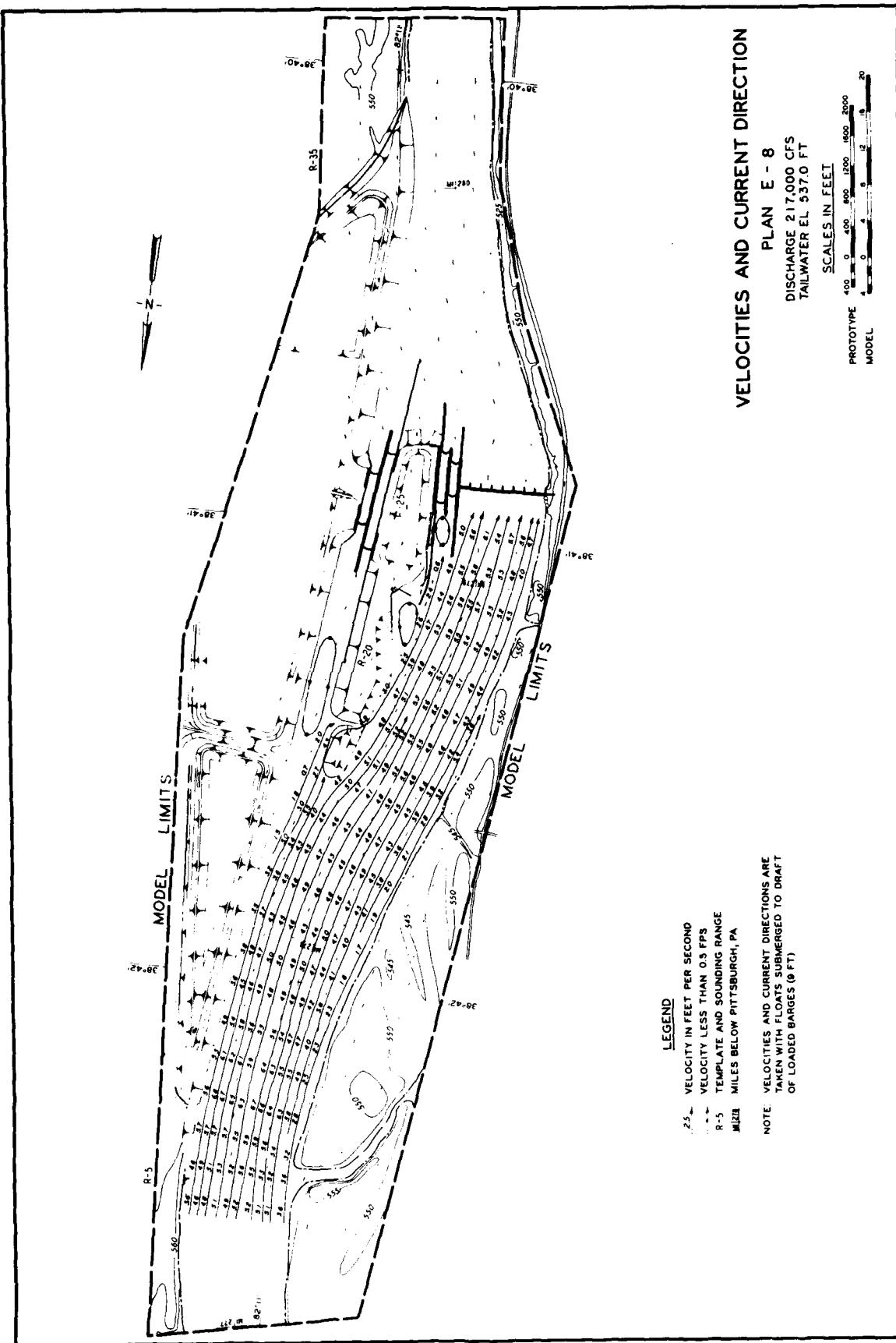


PLATE 25

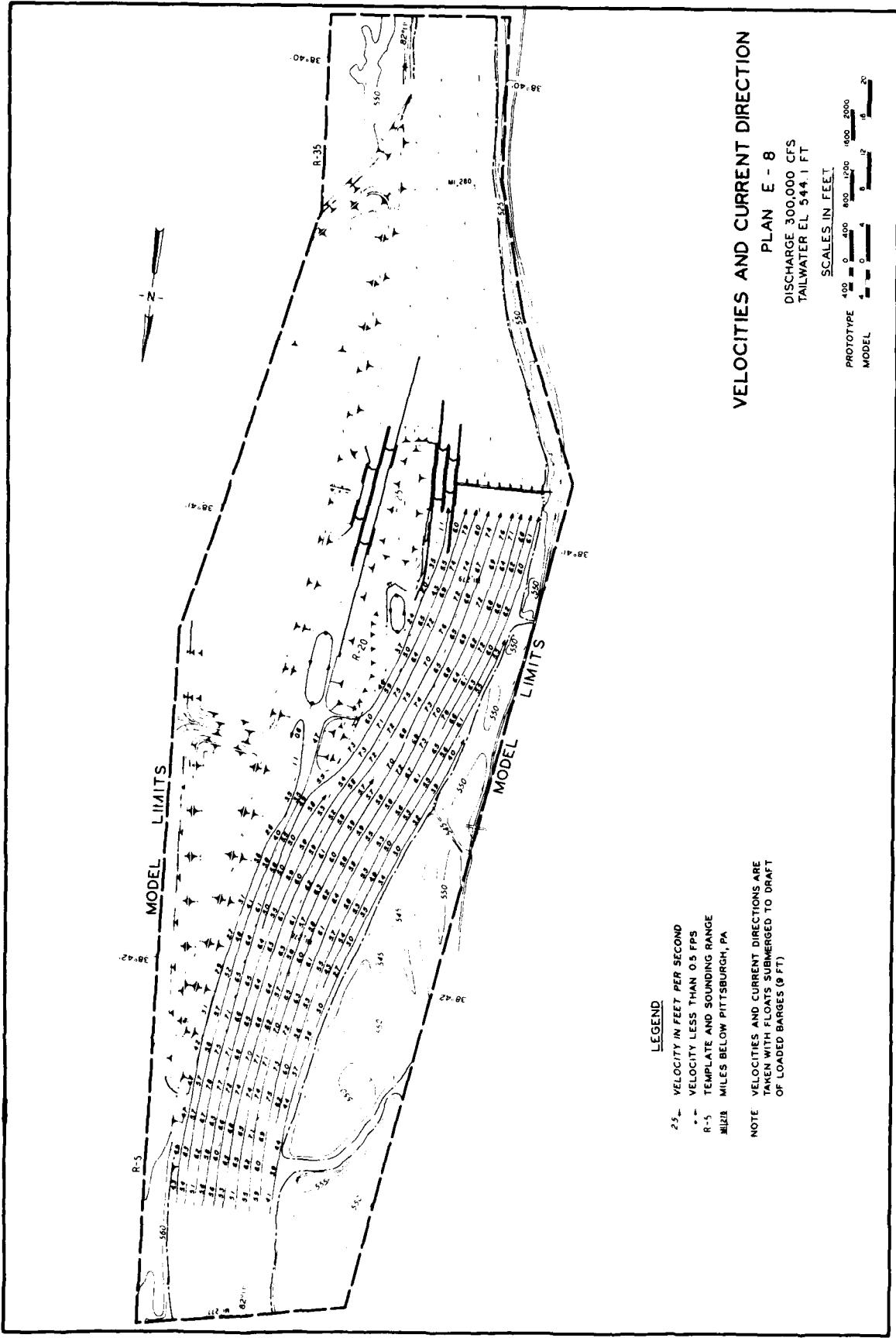
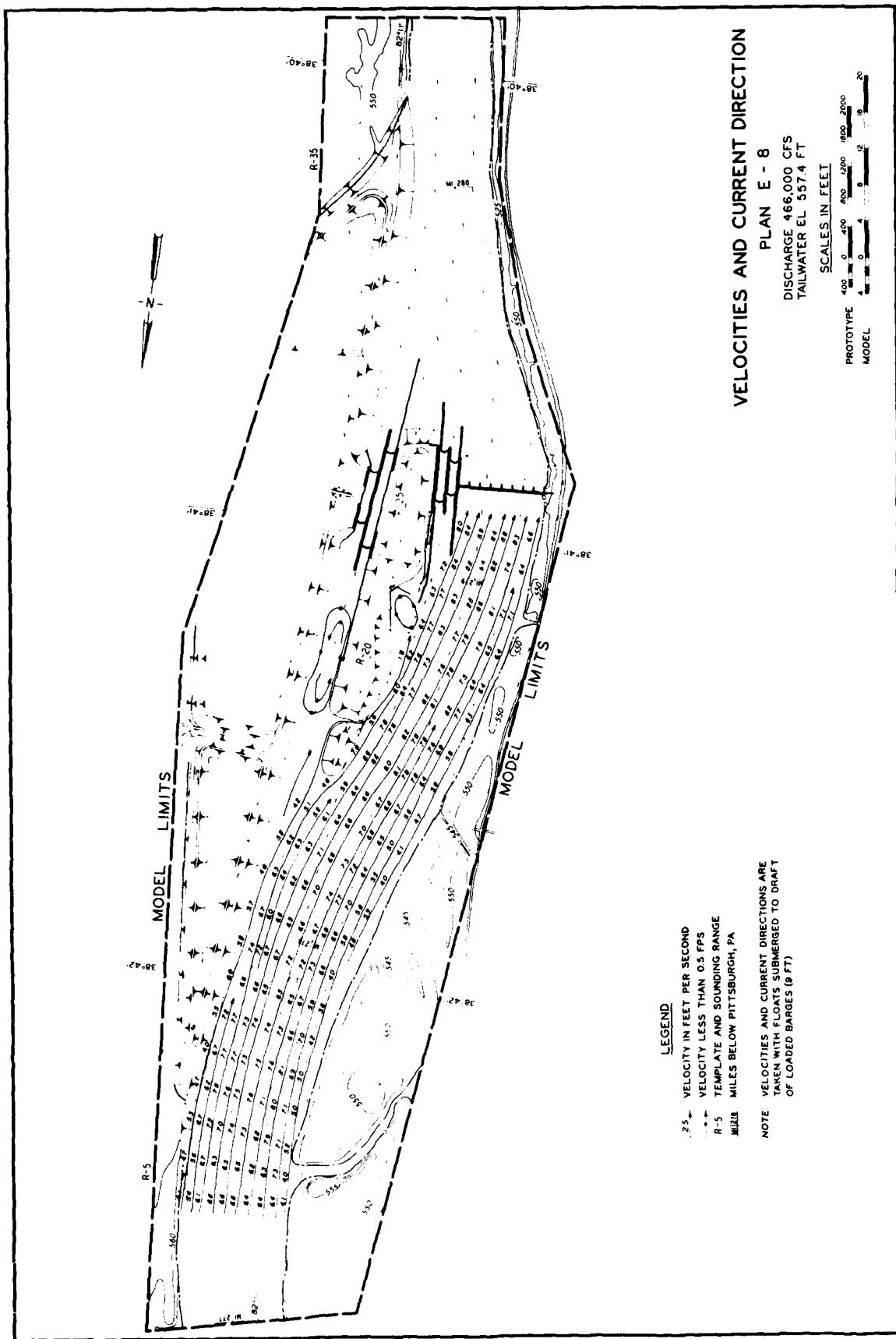


PLATE 26



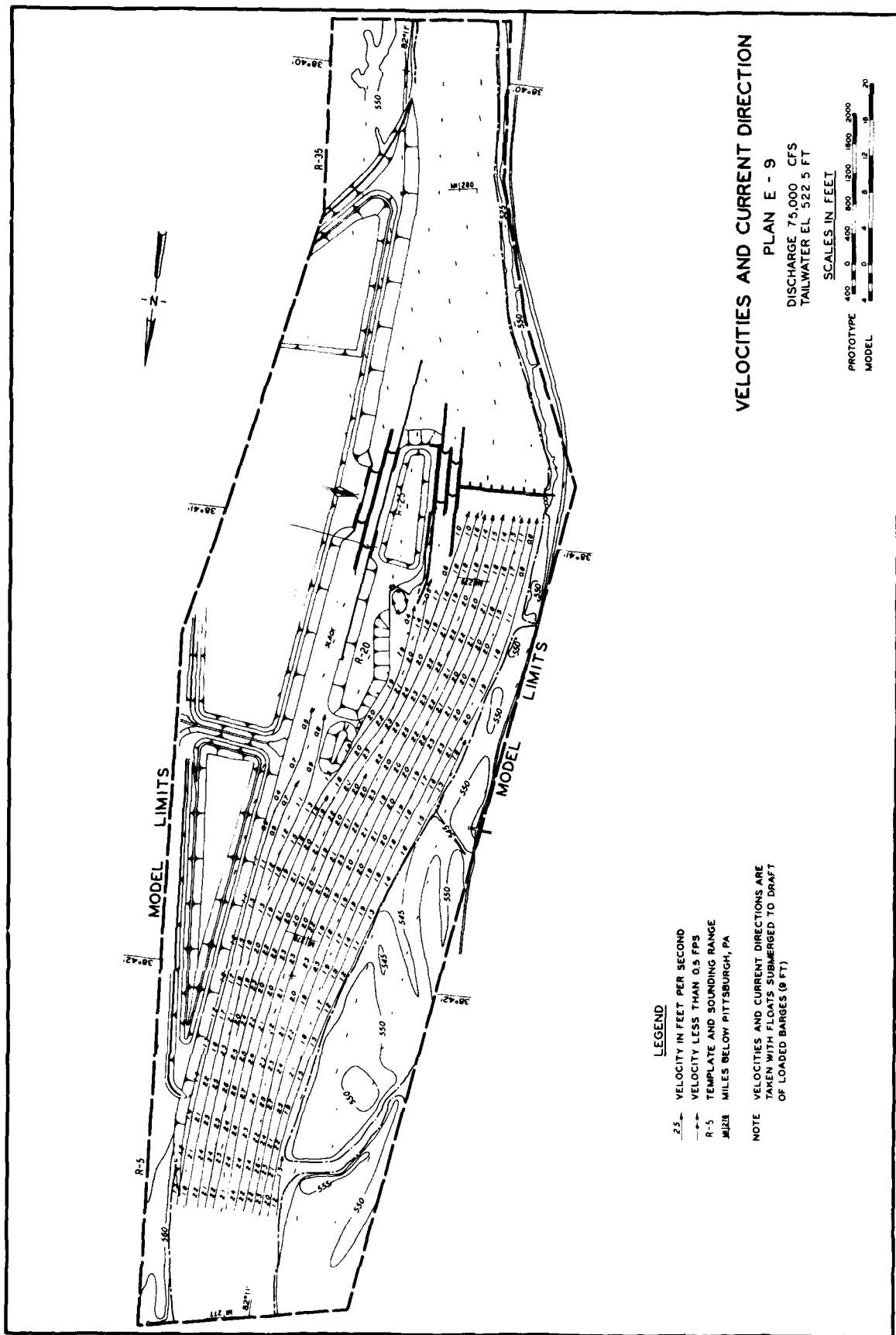
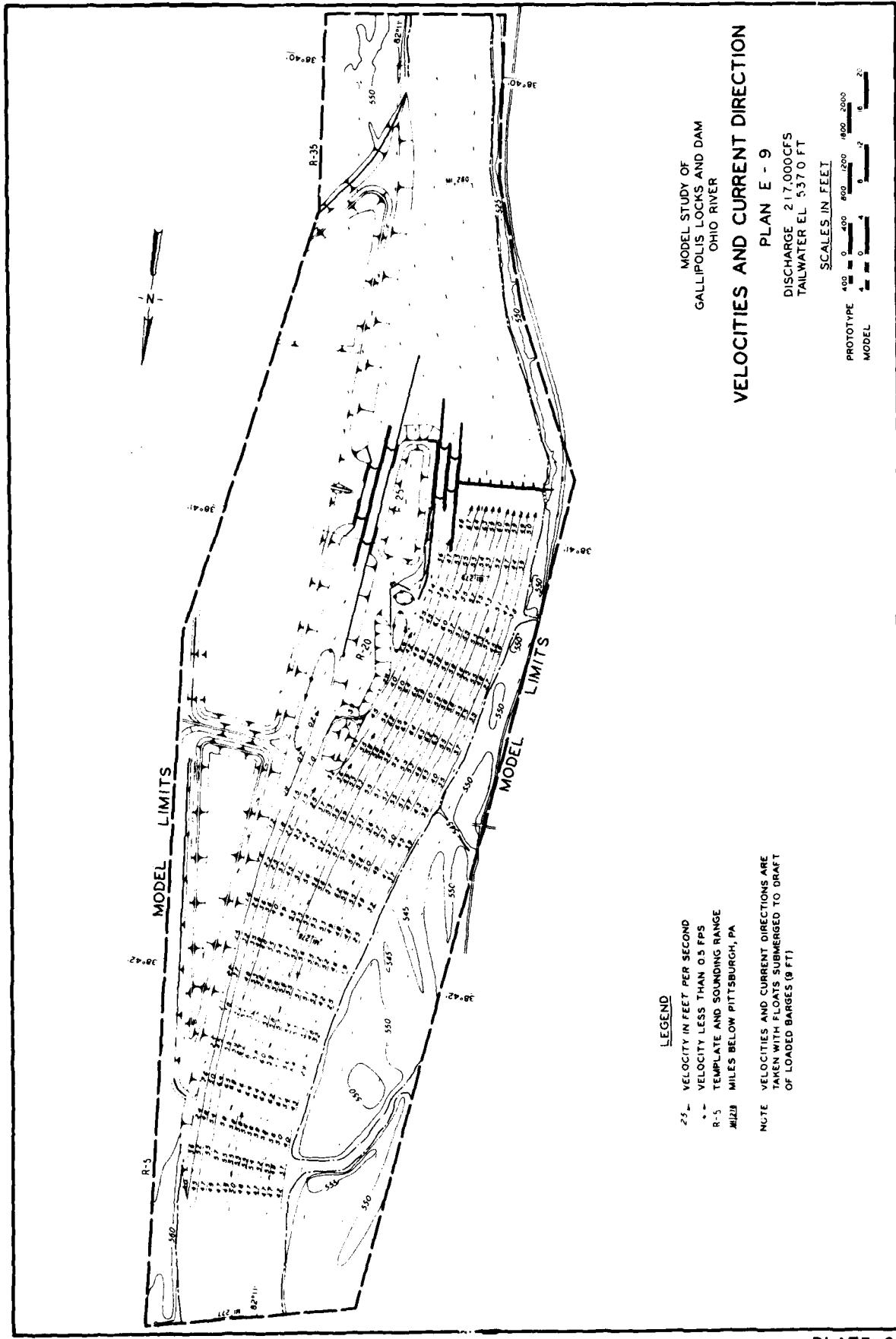
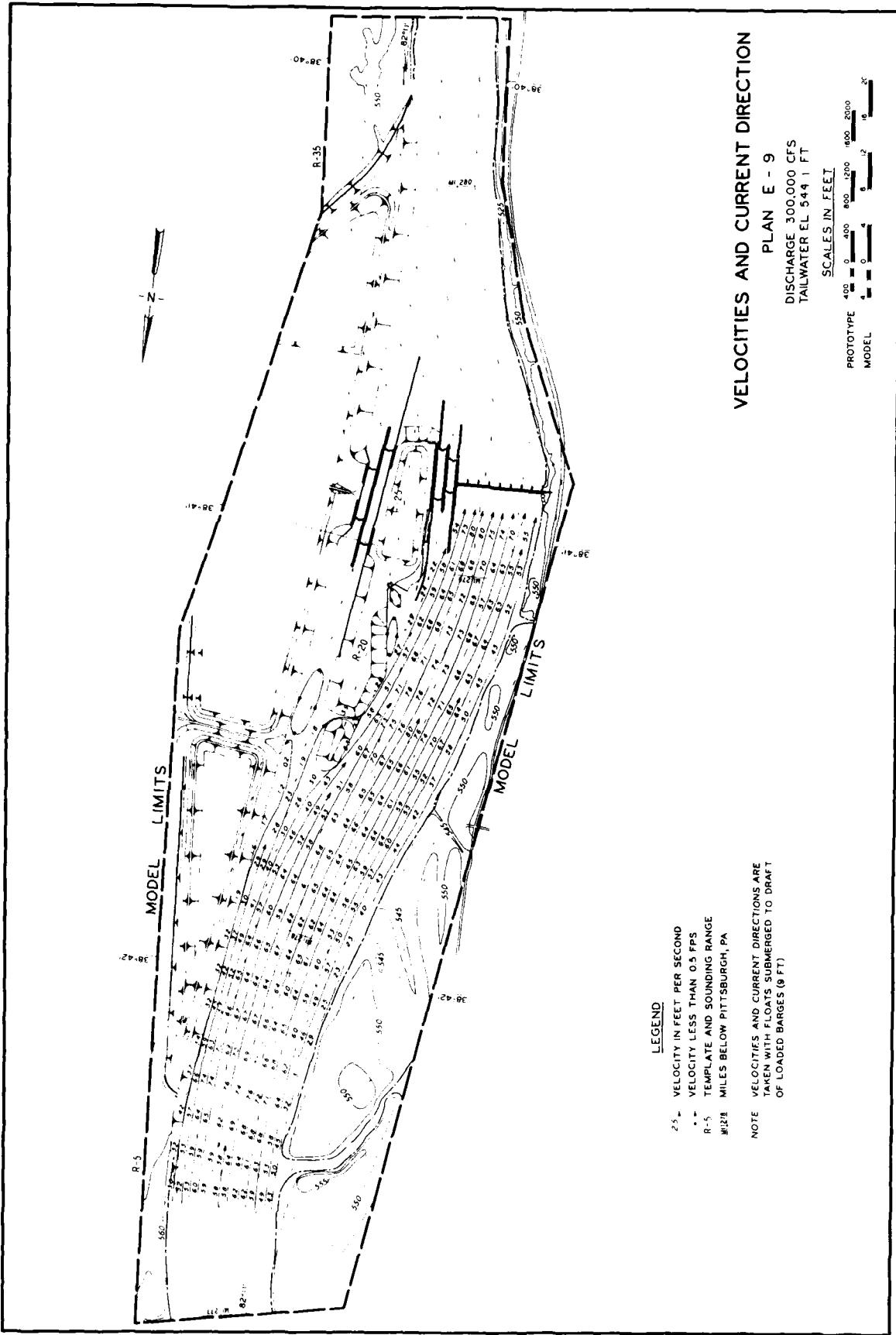
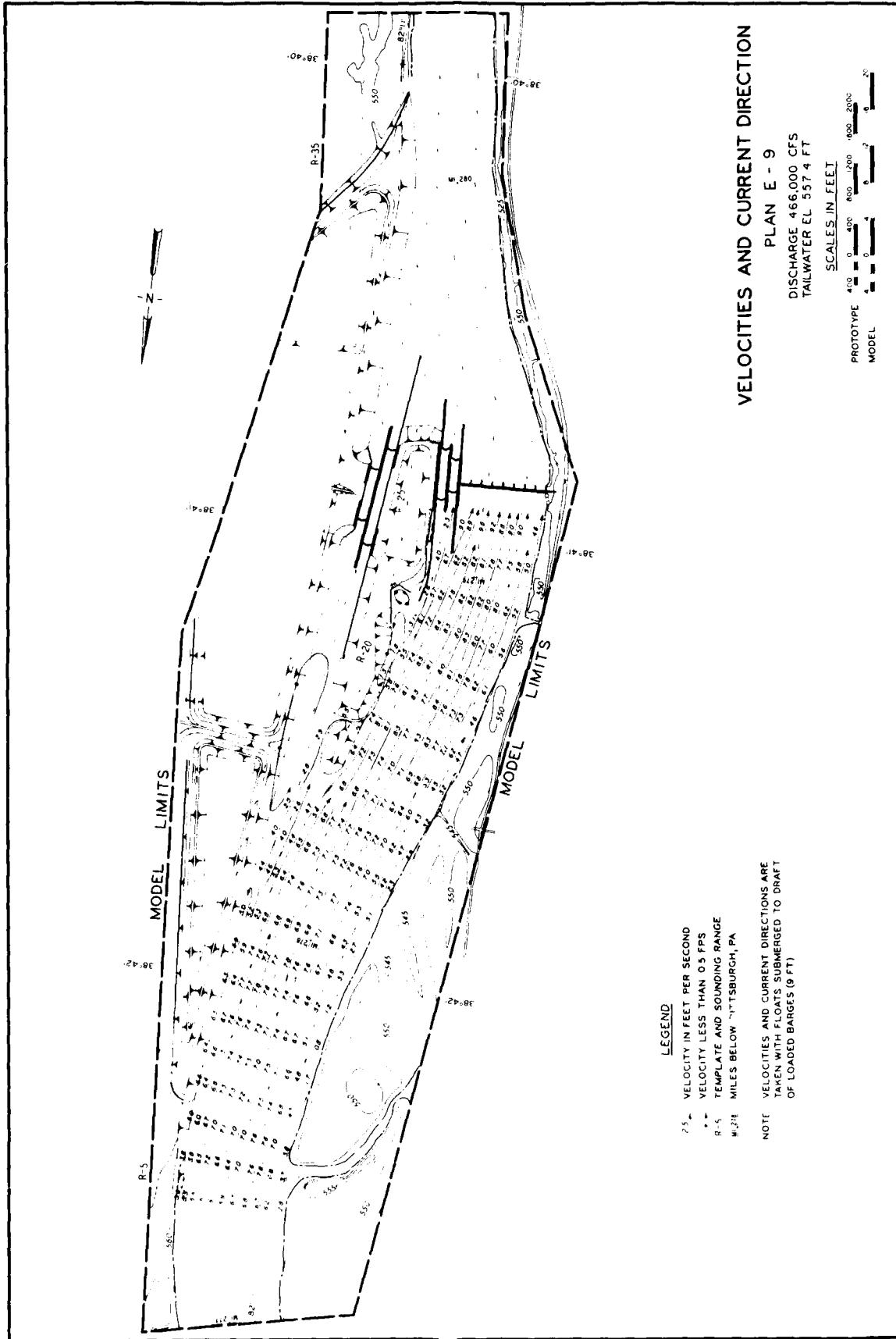


PLATE 28







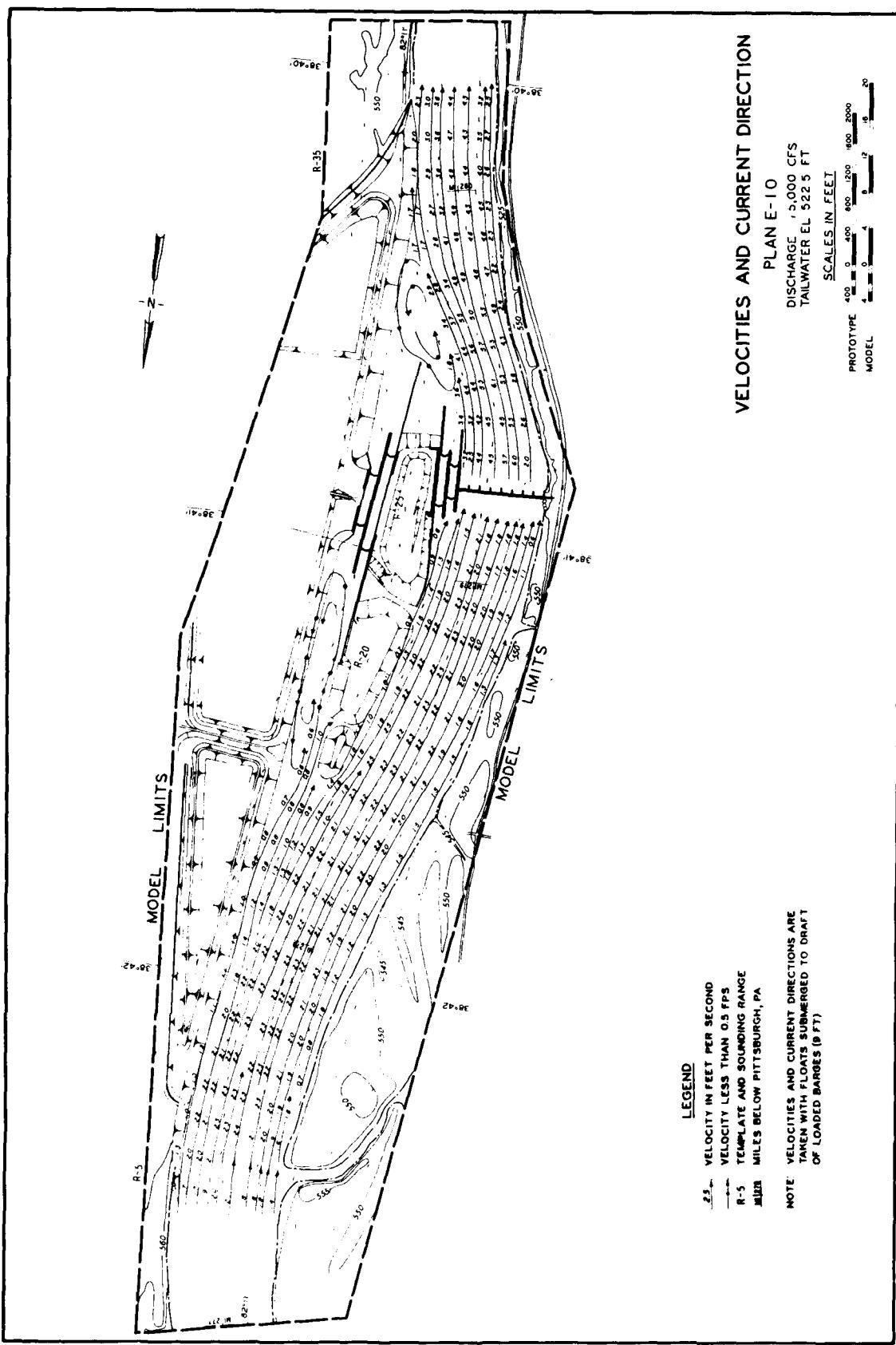
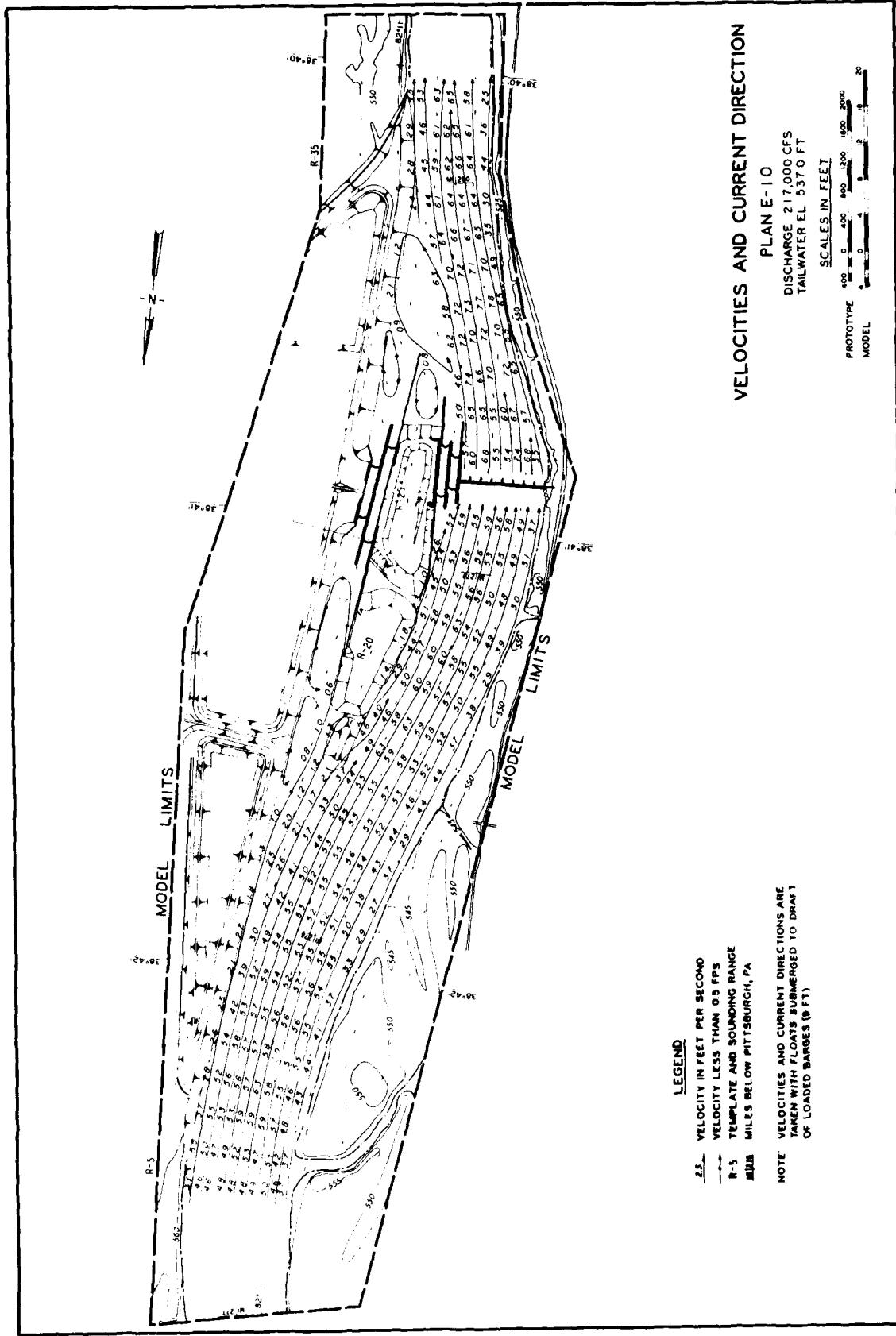


PLATE 32



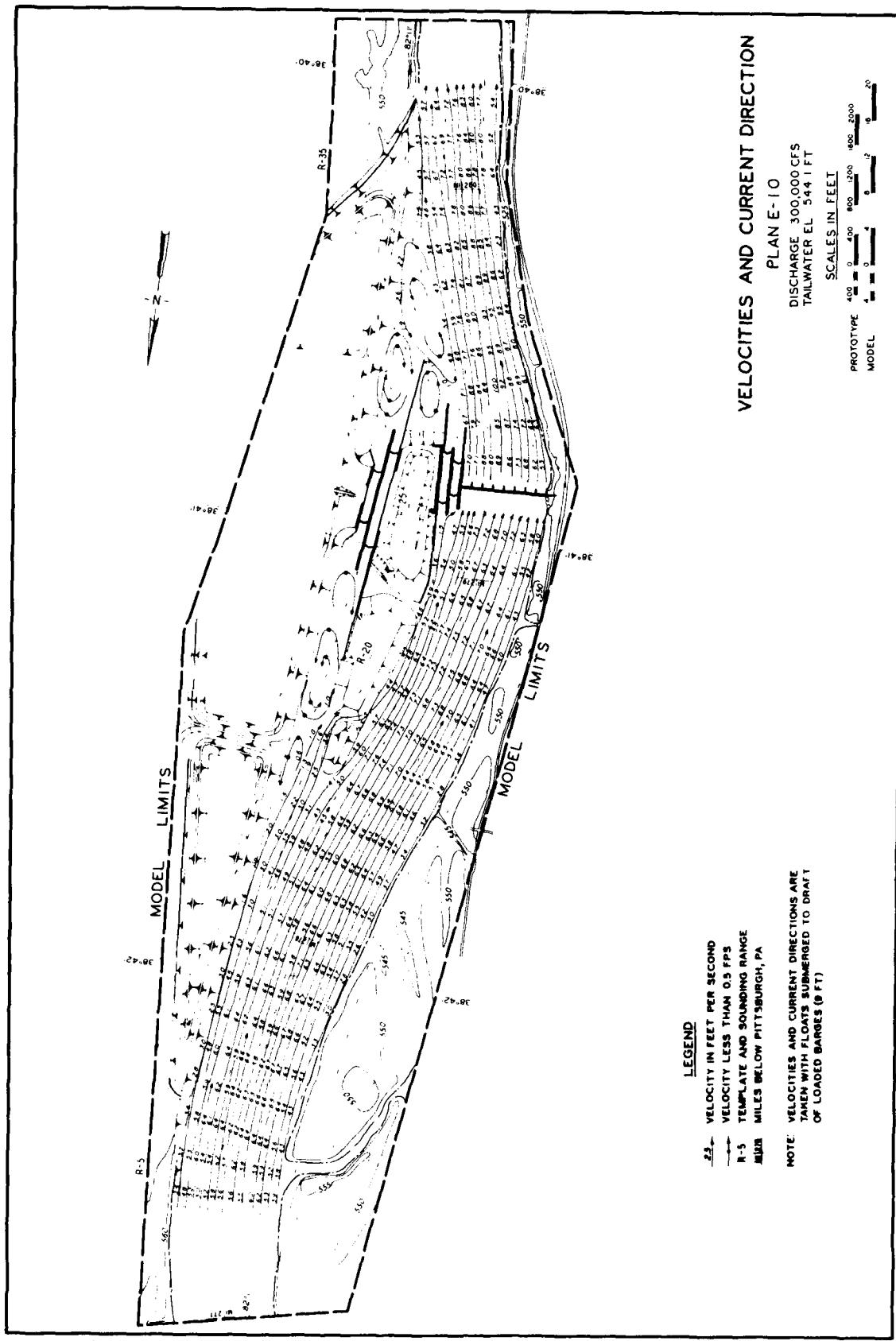
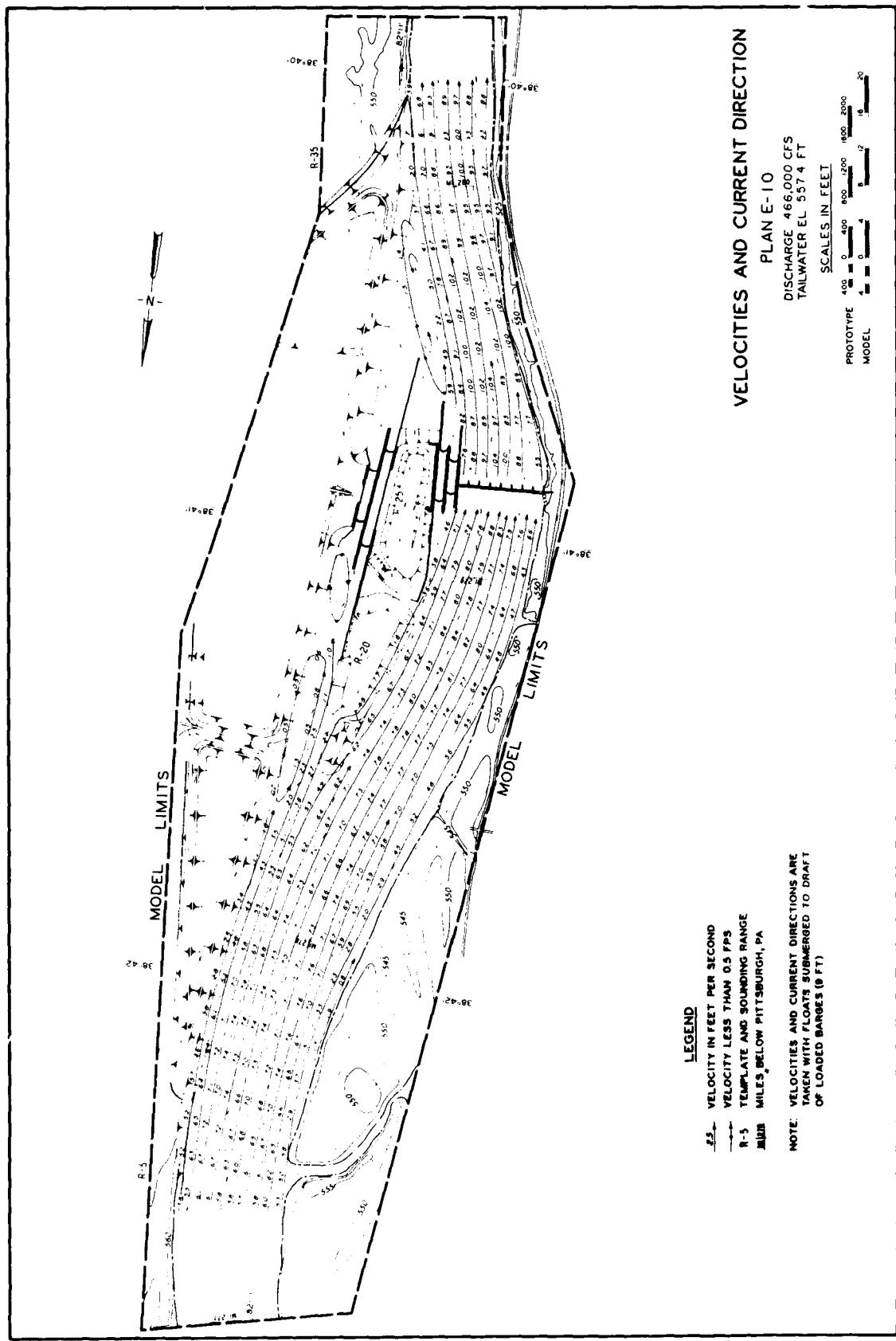


PLATE 34



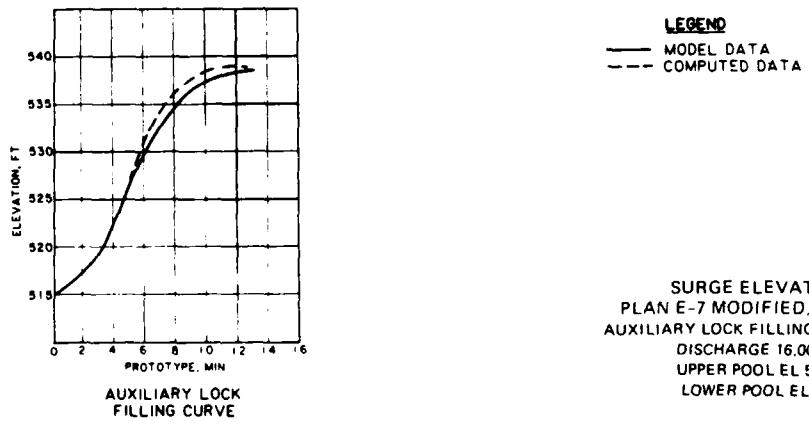
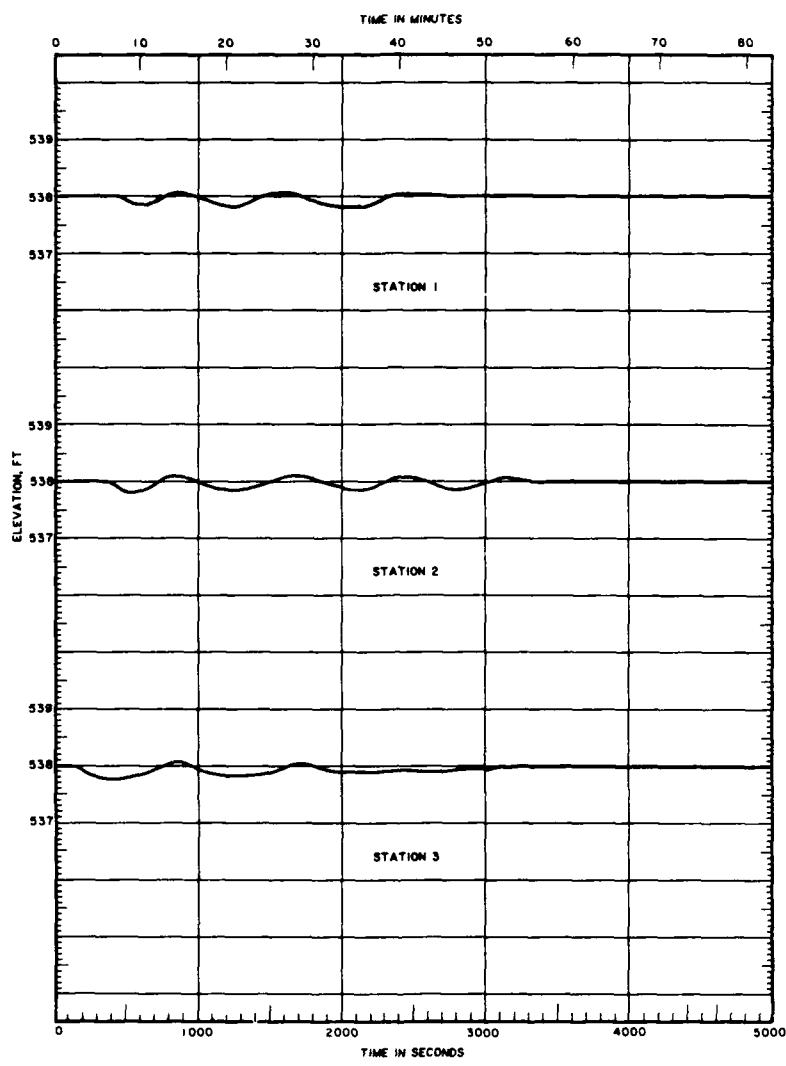
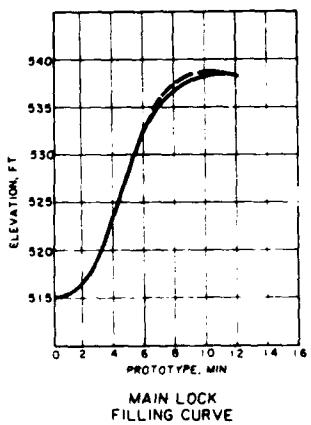
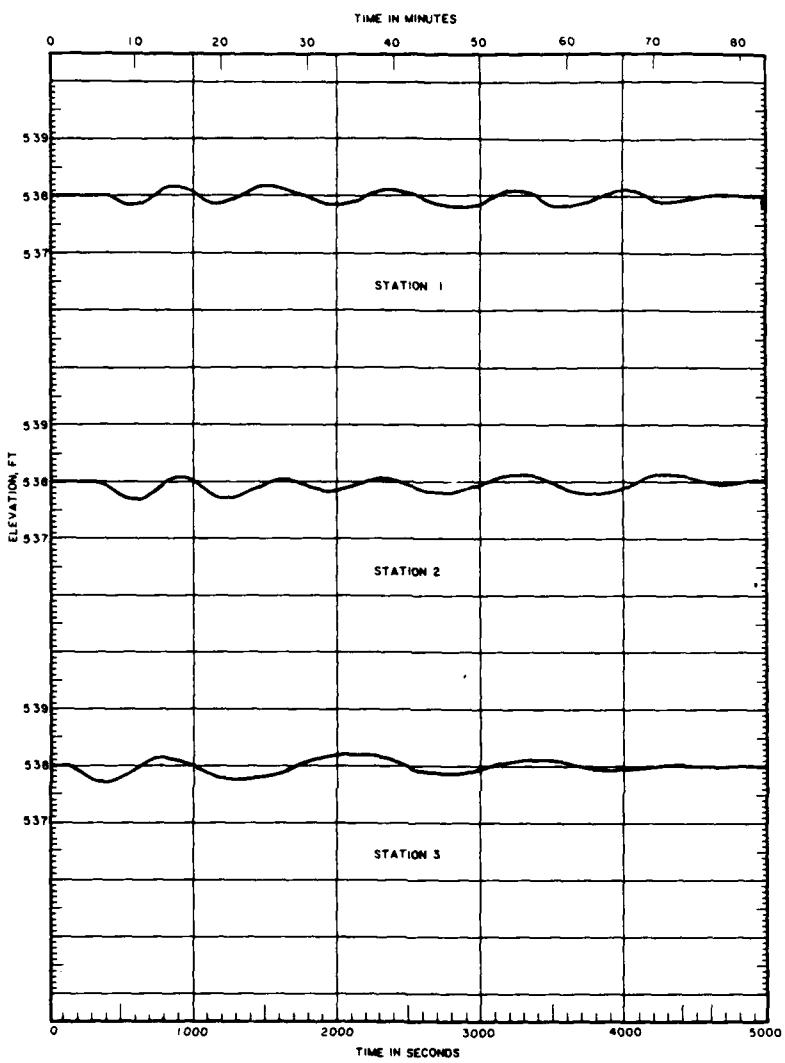
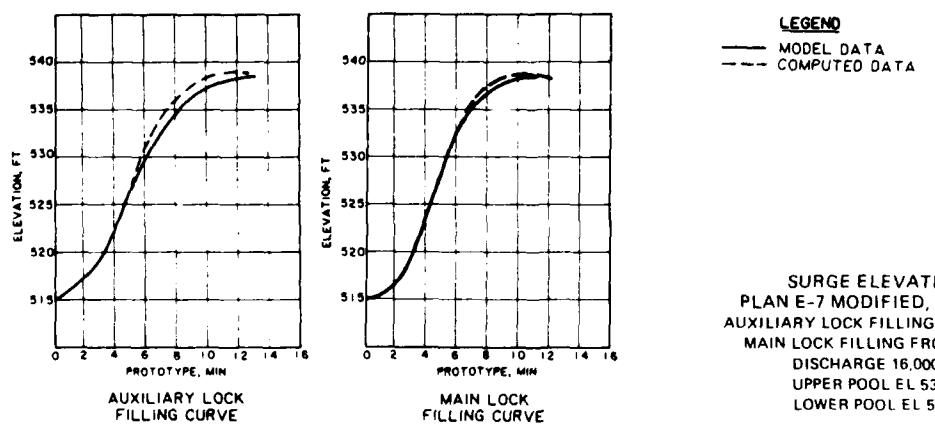
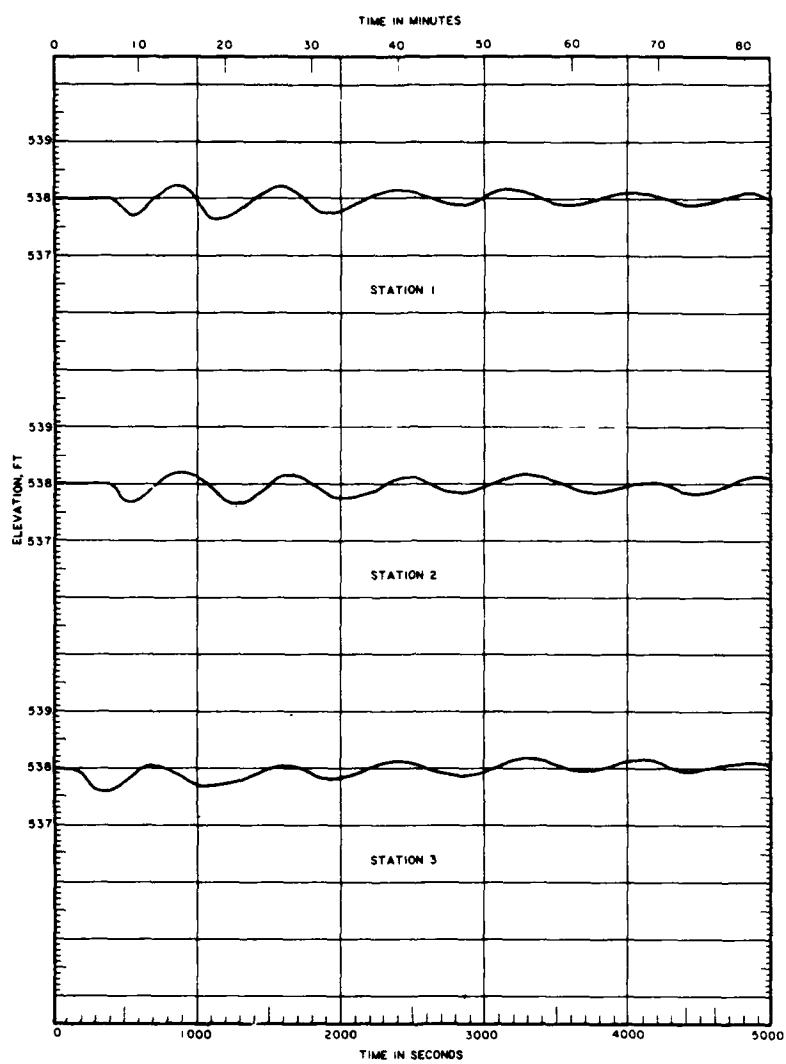
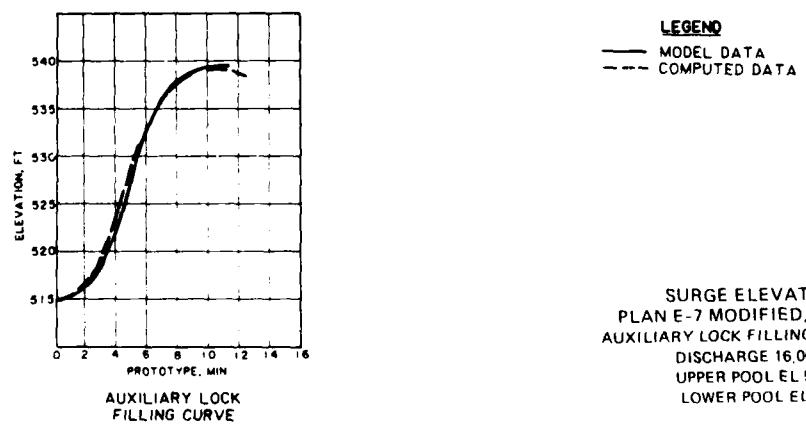
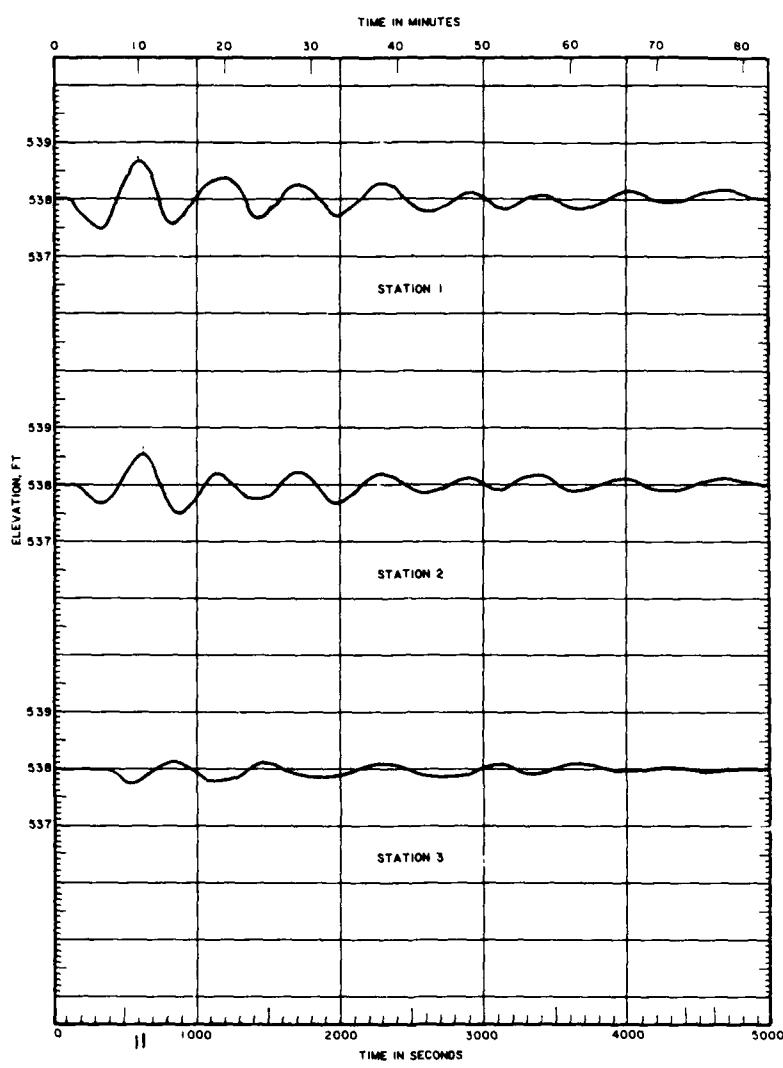


PLATE 36



SURGE ELEVATIONS  
PLAN E-7 MODIFIED, SCHEME 4  
MAIN LOCK FILLING FROM RIVER  
DISCHARGE 16,000 CFS  
UPPER POOL EL 538 0  
LOWER POOL EL 515 0





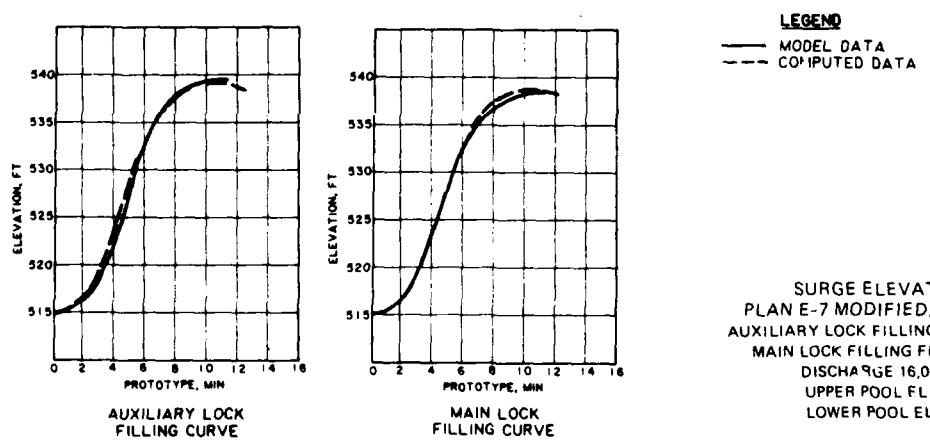
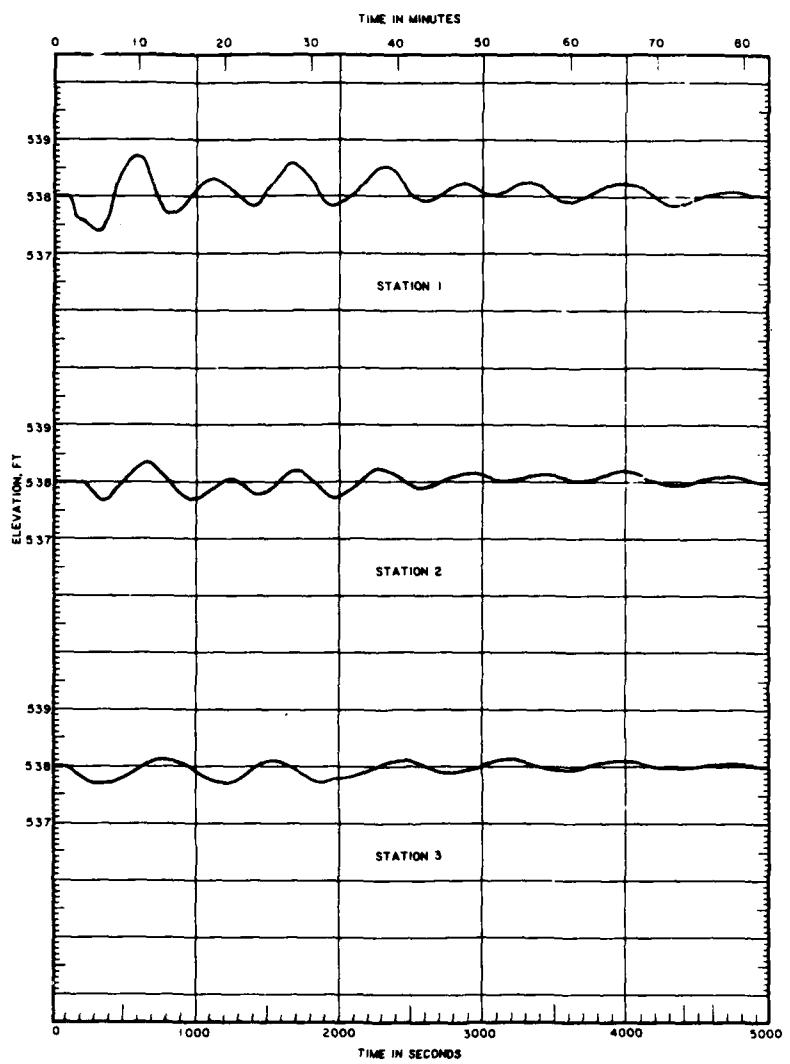
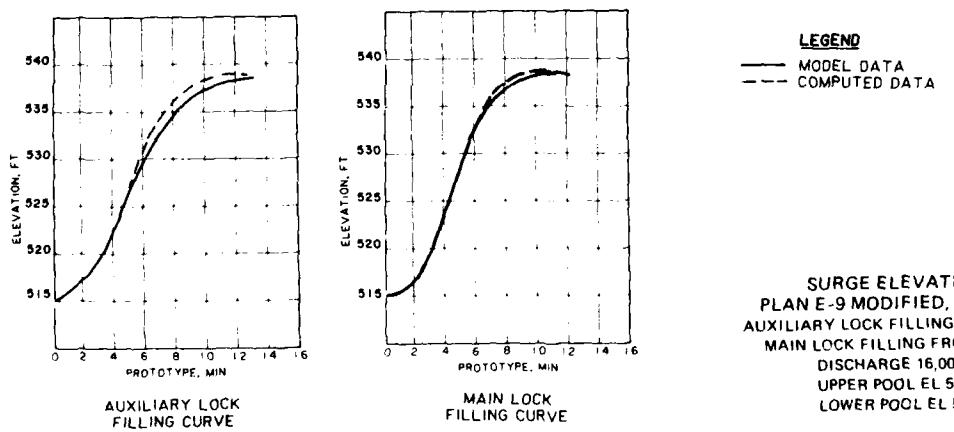
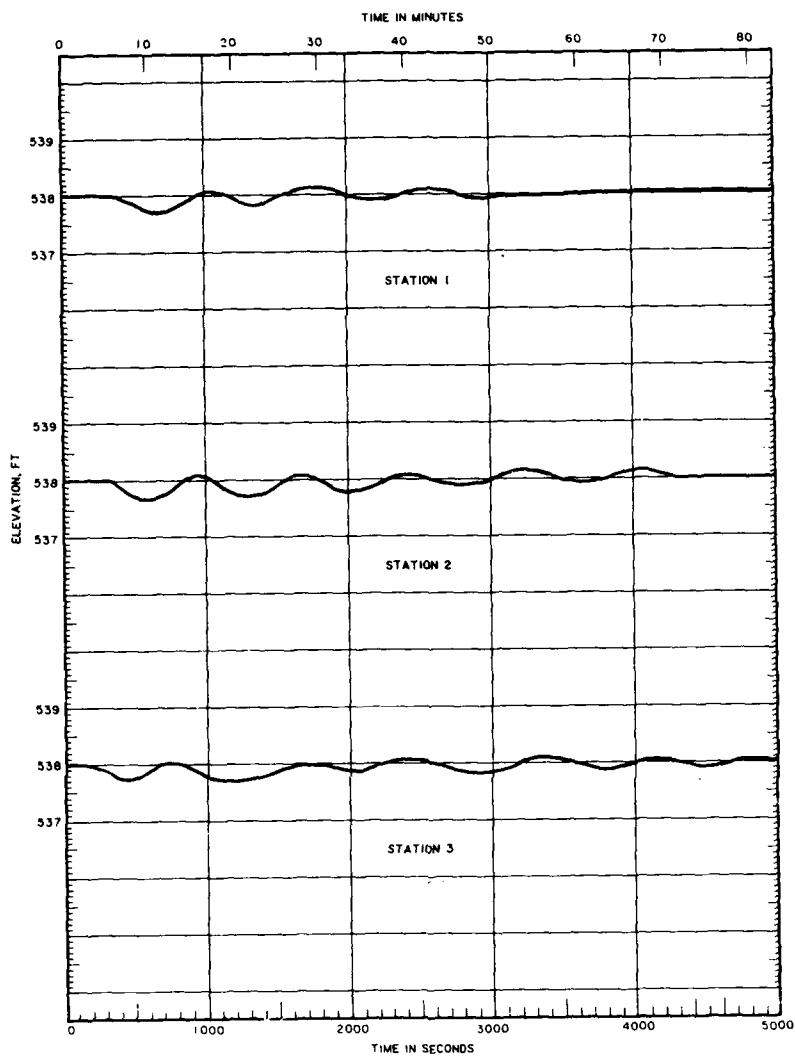
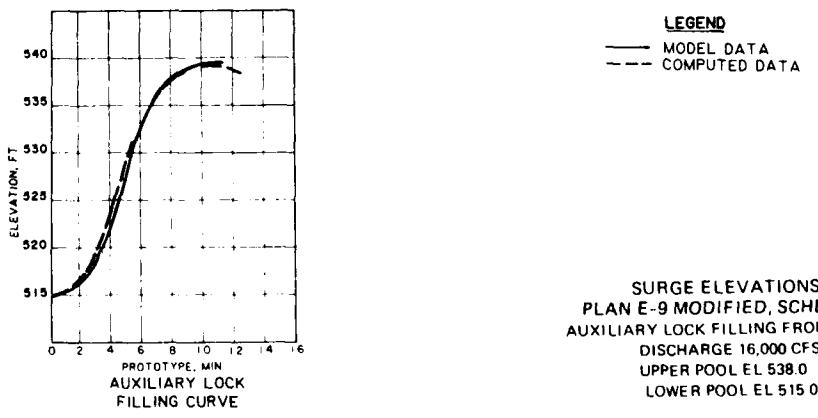
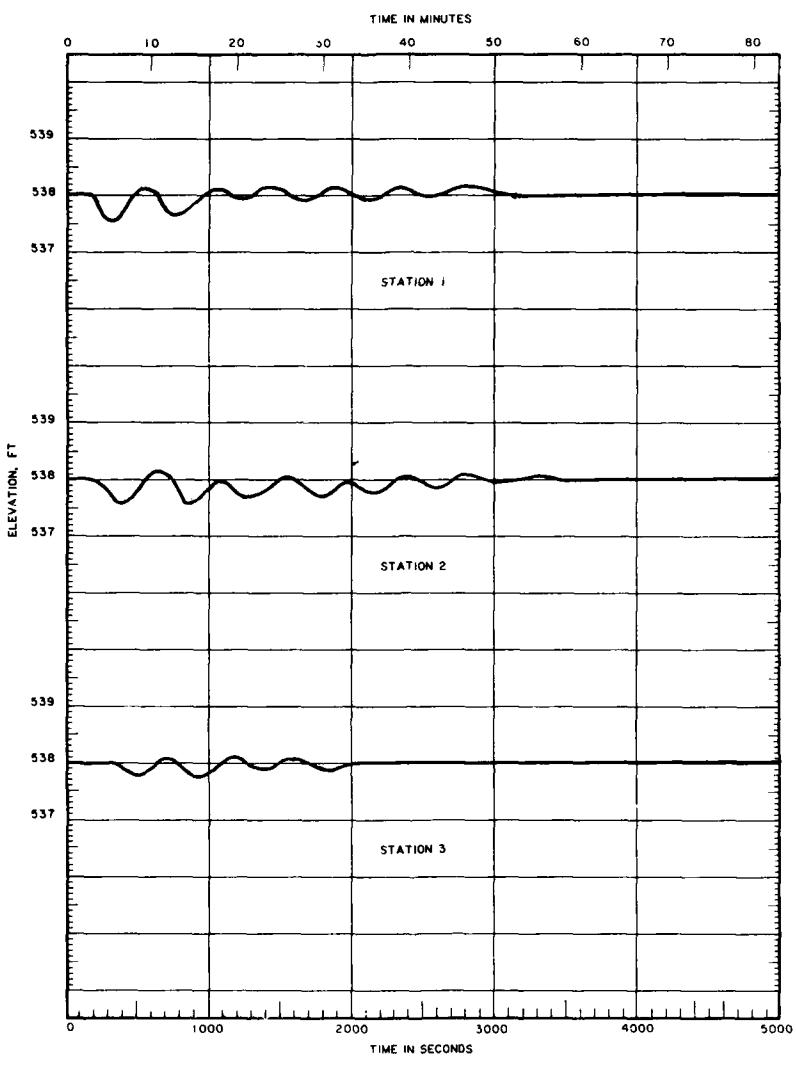
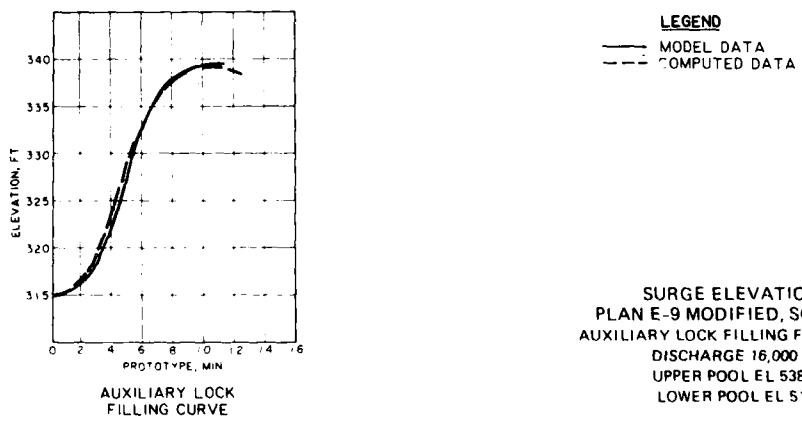
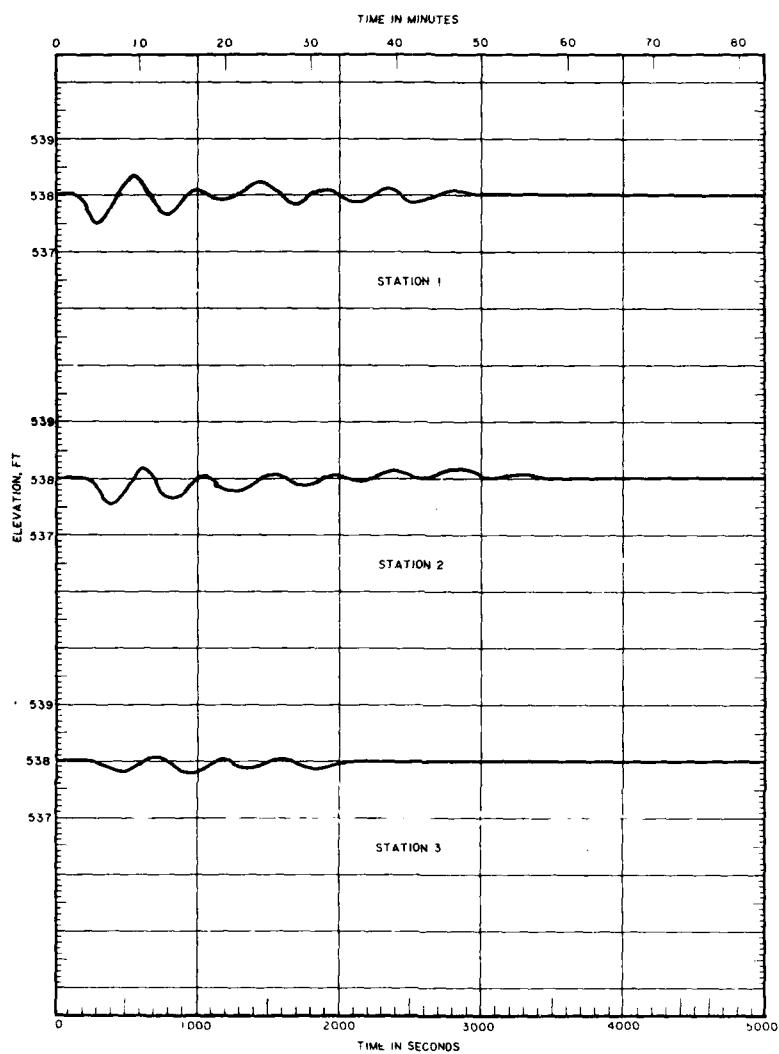
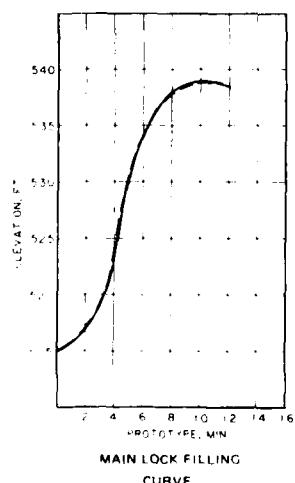
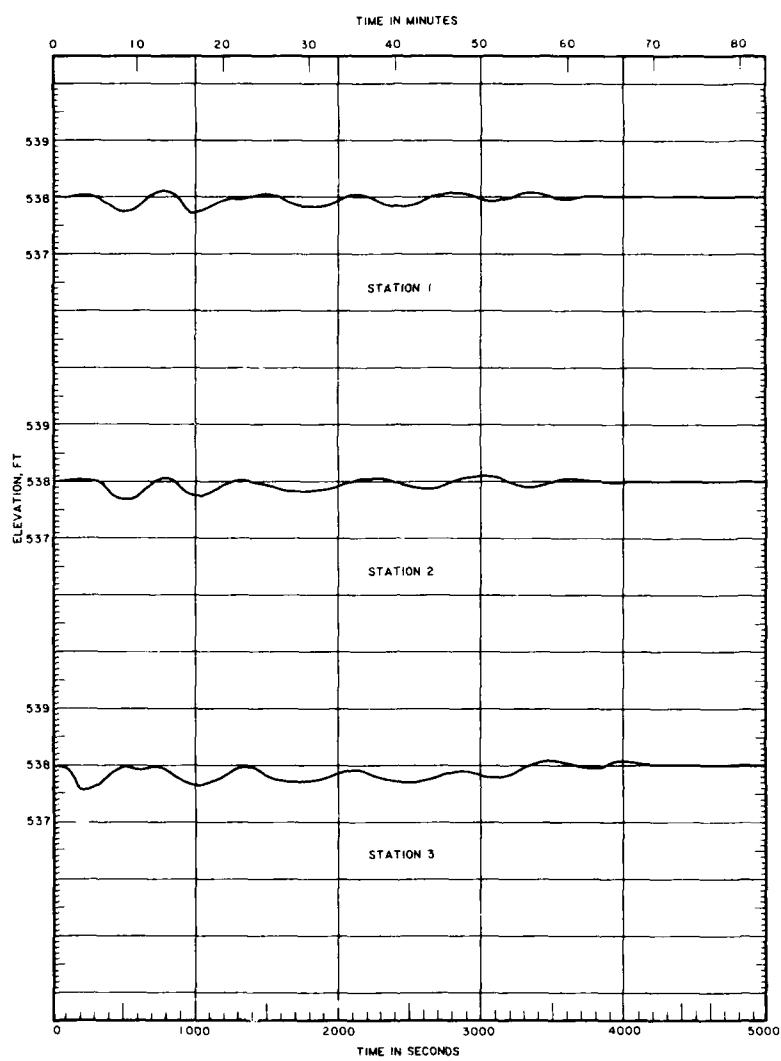


PLATE 40

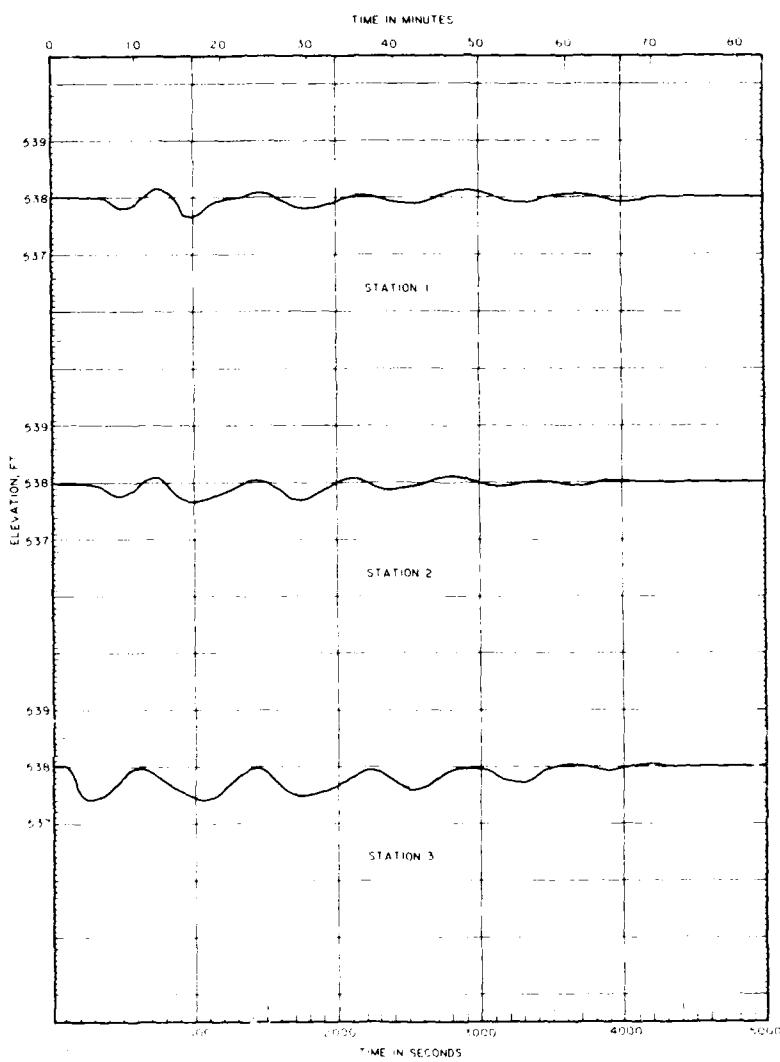








SURGE ELEVATIONS  
PLAN E-10 MODIFIED, SCHEME 9  
MAIN LOCK FILLING  
DISCHARGE 16,000 CFS  
UPPER POOL EL 538.0  
LOWER POOL EL 515.0



LEGEND  
— MODEL DATA  
- - - COMPUTED DATA

AUXILIARY LOCK FILLING CURVE

MAIN LOCK FILLING CURVE

SURGE ELEVATION  
PLAN E 10 MODIFIED SCHEME 9  
MAIN LOCK FILLING  
AUXILIARY LOCK FILLING  
DISCHARGE 16 000 CFS  
UPPER POOL EL 538.0  
LOWER POOL EL 515.0

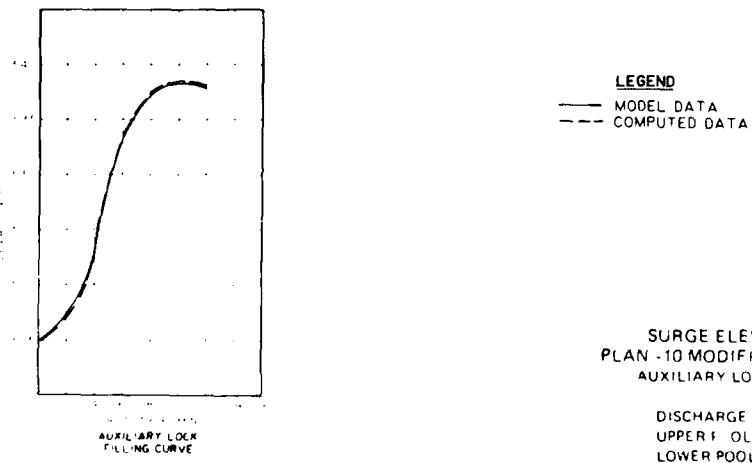
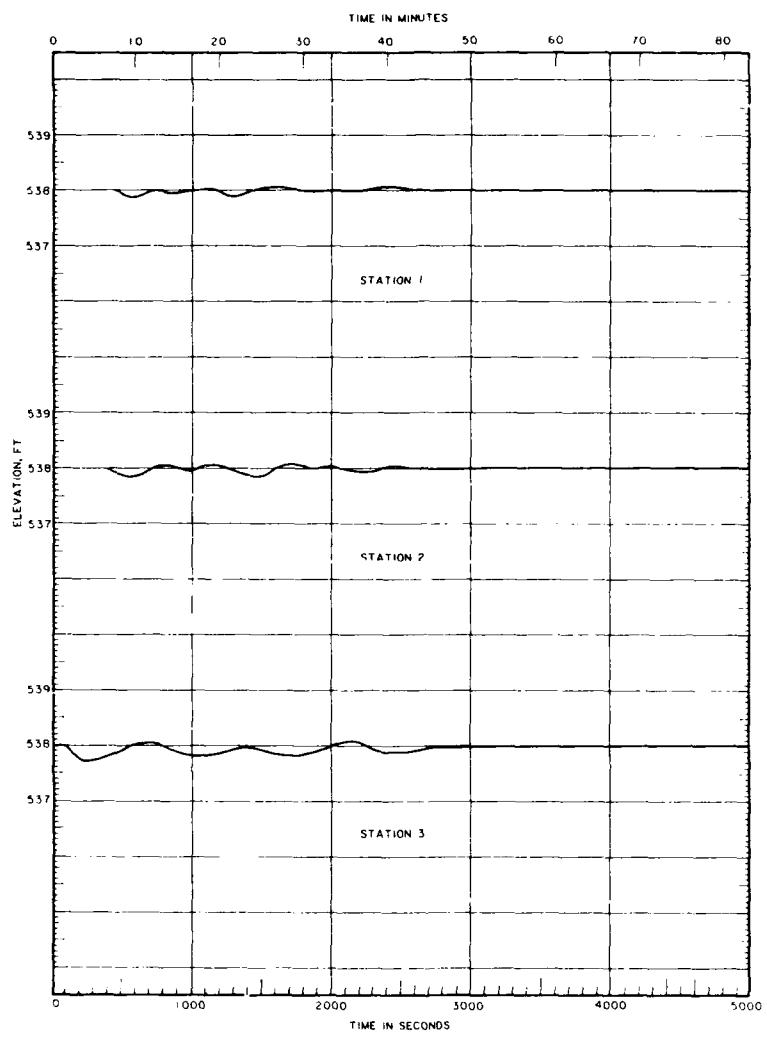
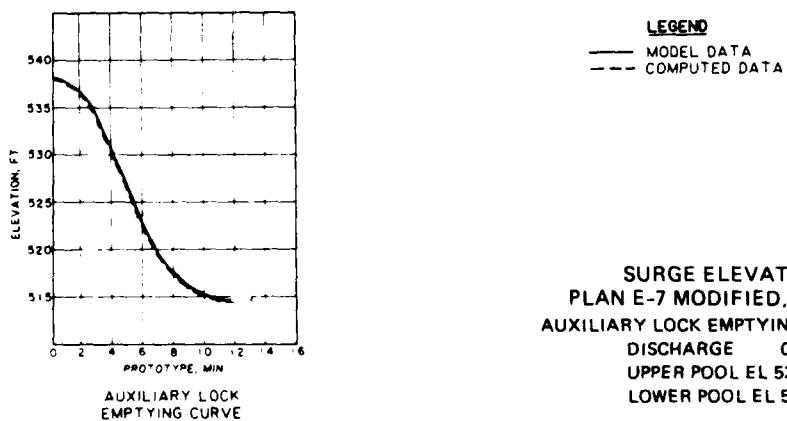
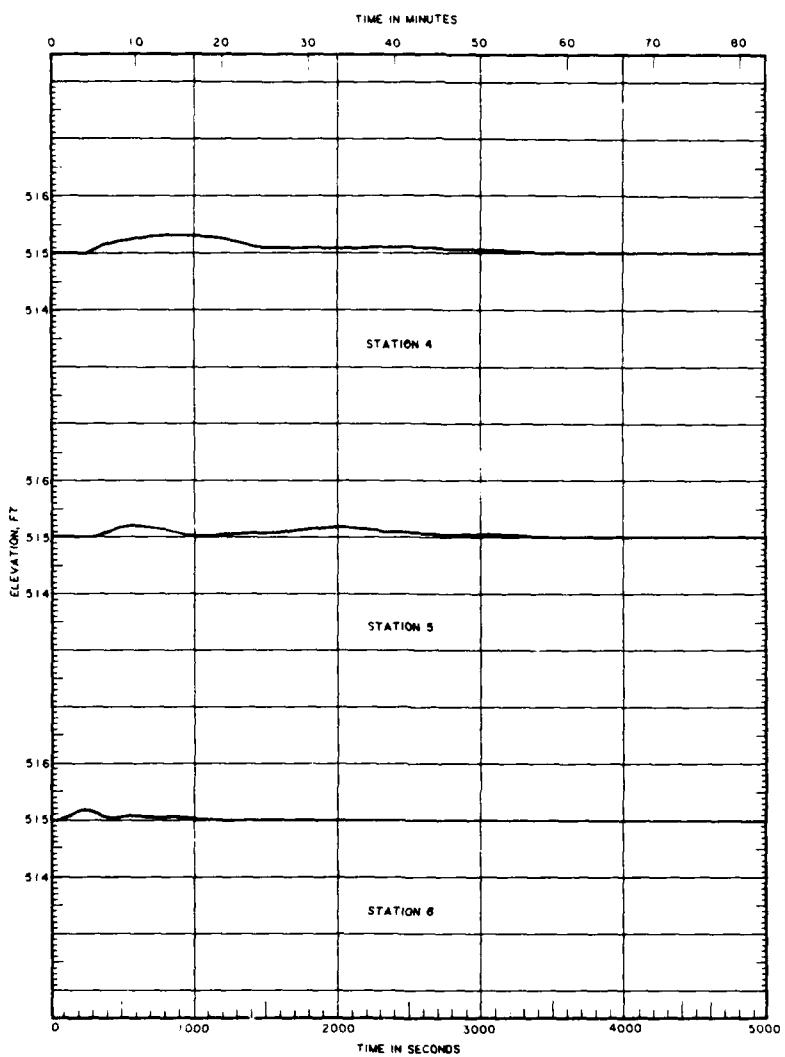
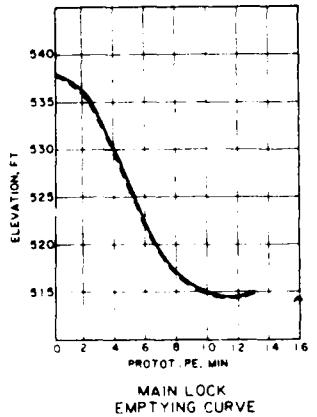
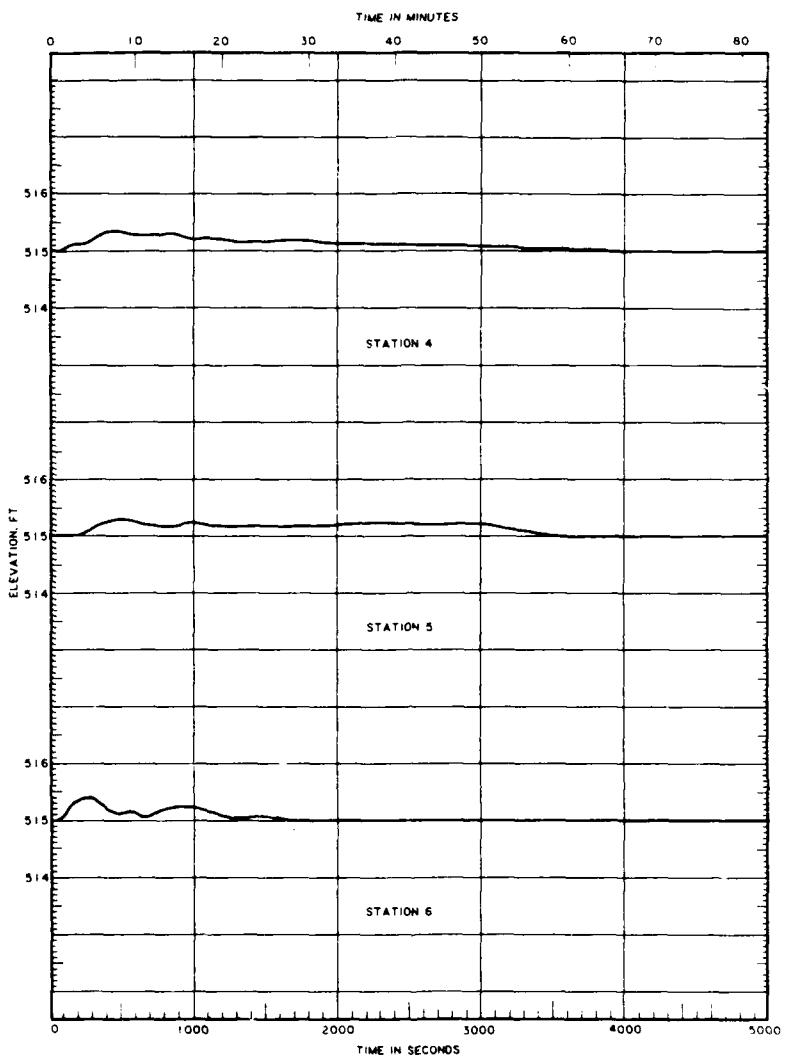


PLATE 46

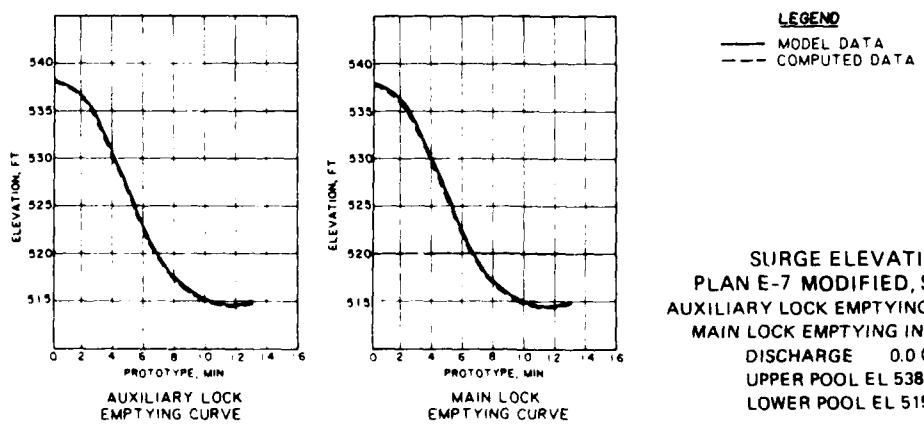
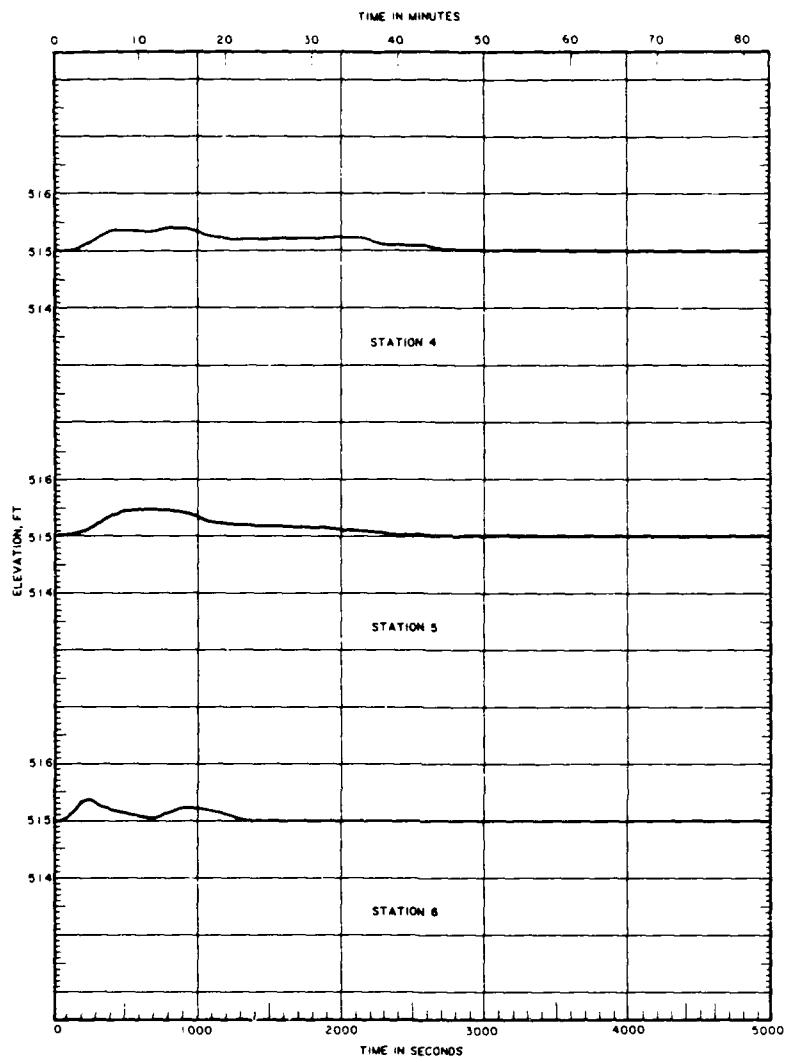




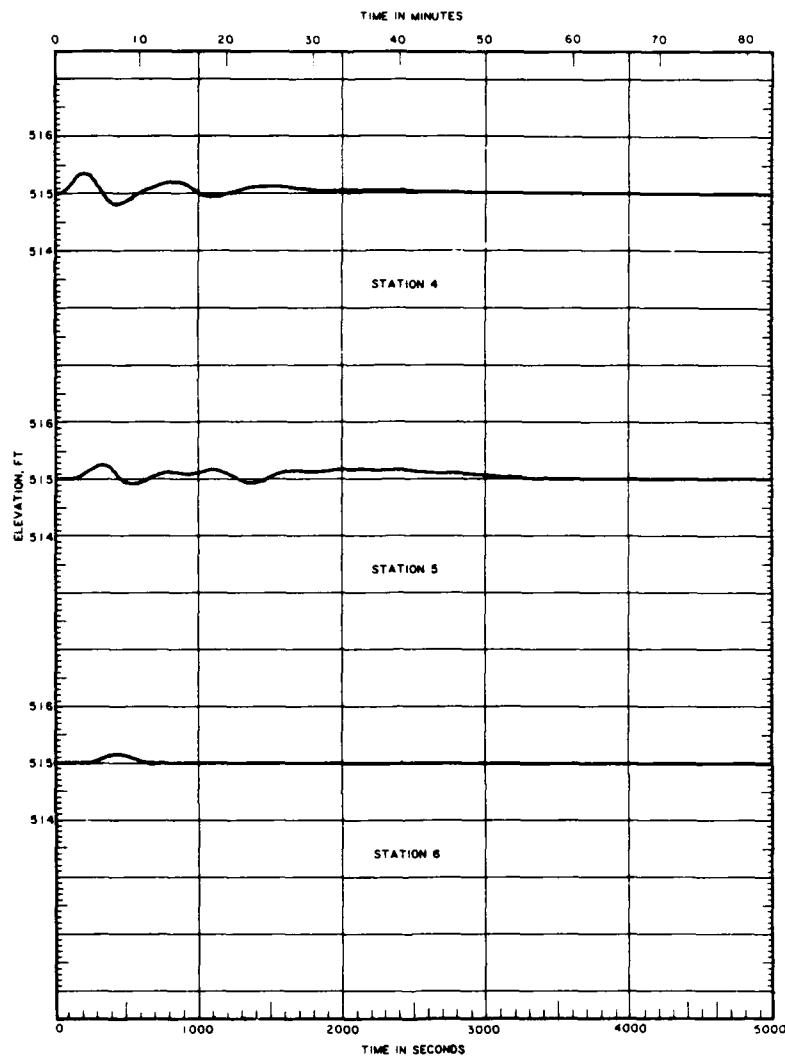
LEGEND

— MODEL DATA  
- - - COMPUTED DATA

SURGE ELEVATIONS  
PLAN E-7 MODIFIED, SCHEME 7  
MAIN LOCK EMPTYING INTO RIVER  
DISCHARGE 0.0 CFS  
UPPER POOL EL 538.0  
LOWER POOL EL 515.0

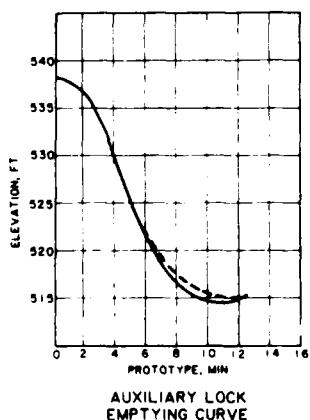


SURGE ELEVATIONS  
PLAN E-7 MODIFIED, SCHEME 7  
AUXILIARY LOCK EMPTYING INTO RIVER  
MAIN LOCK EMPTYING INTO RIVER  
DISCHARGE 0.0 CFS  
UPPER POOL EL 538.0  
LOWER POOL EL 515.0

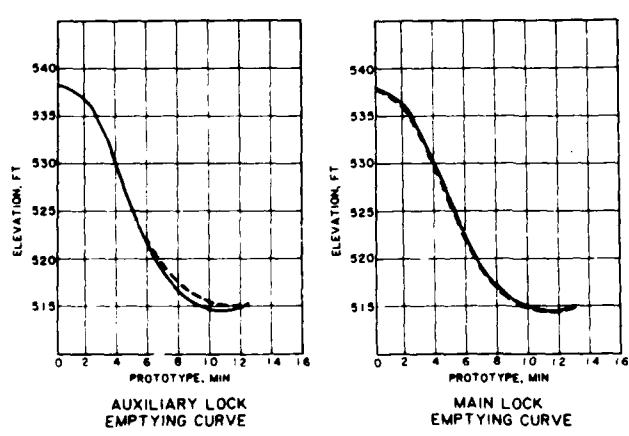
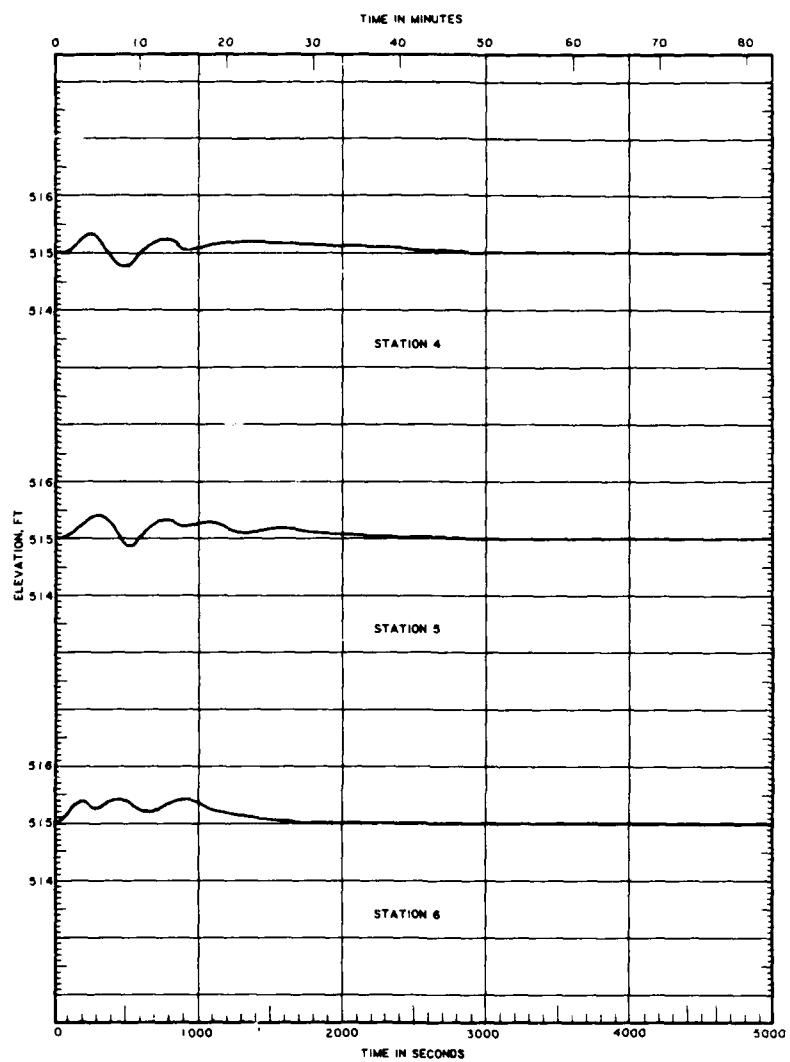


LEGEND

- MODEL DATA
- - COMPUTED DATA



SURGE ELEVATIONS  
PLAN E-7 MODIFIED, SCHEME 8  
AUXILIARY LOCK EMPTYING INTO CANAL  
DISCHARGE 0.0 CFS  
UPPER POOL EL 538.0  
LOWER POOL EL 515.0



LEGEND

— MODEL DATA  
- - - COMPUTED DATA

SURGE ELEVATIONS  
PLAN E-7 MODIFIED, SCHEME 8  
AUXILIARY LOCK EMPTYING INTO CANAL  
MAIN LOCK EMPTYING INTO RIVER  
DISCHARGE 0.0 CFS  
UPPER POOL EL 538.0  
LOWER POOL EL 515.0

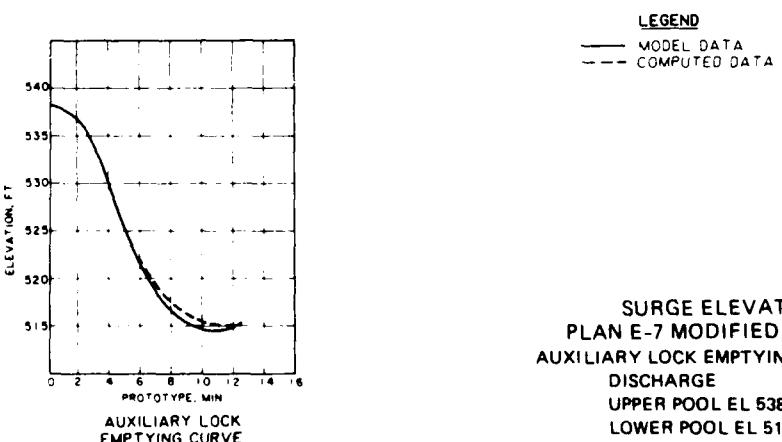
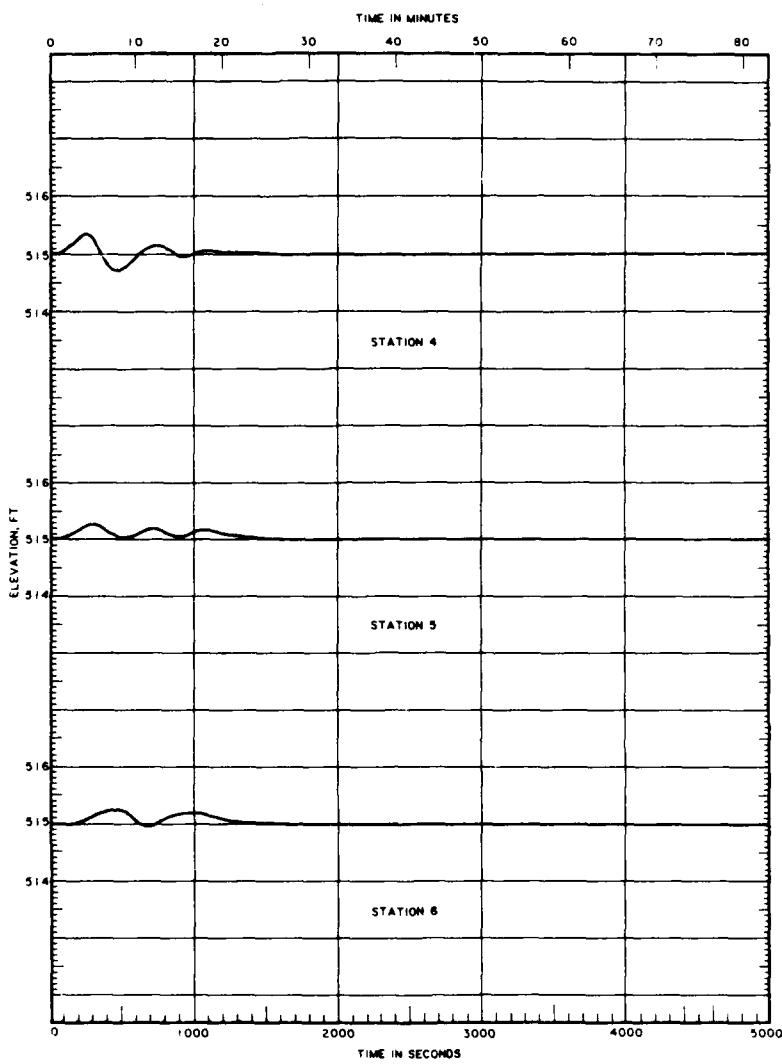
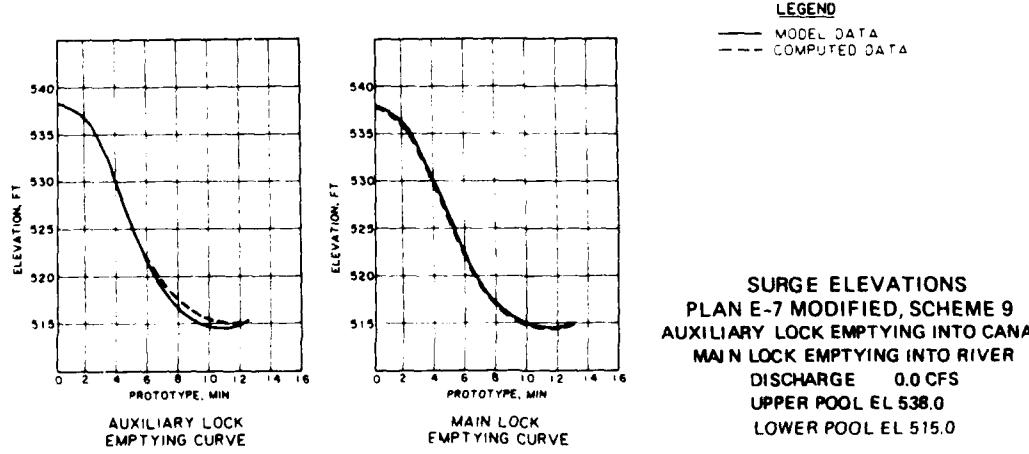
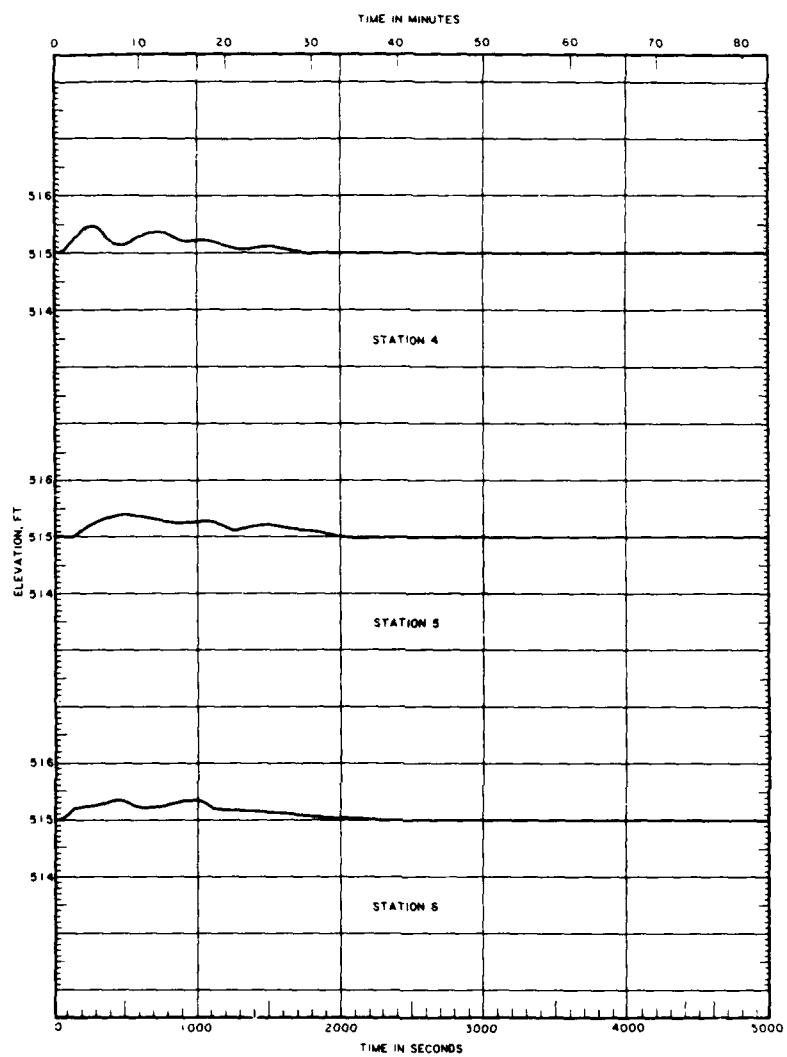
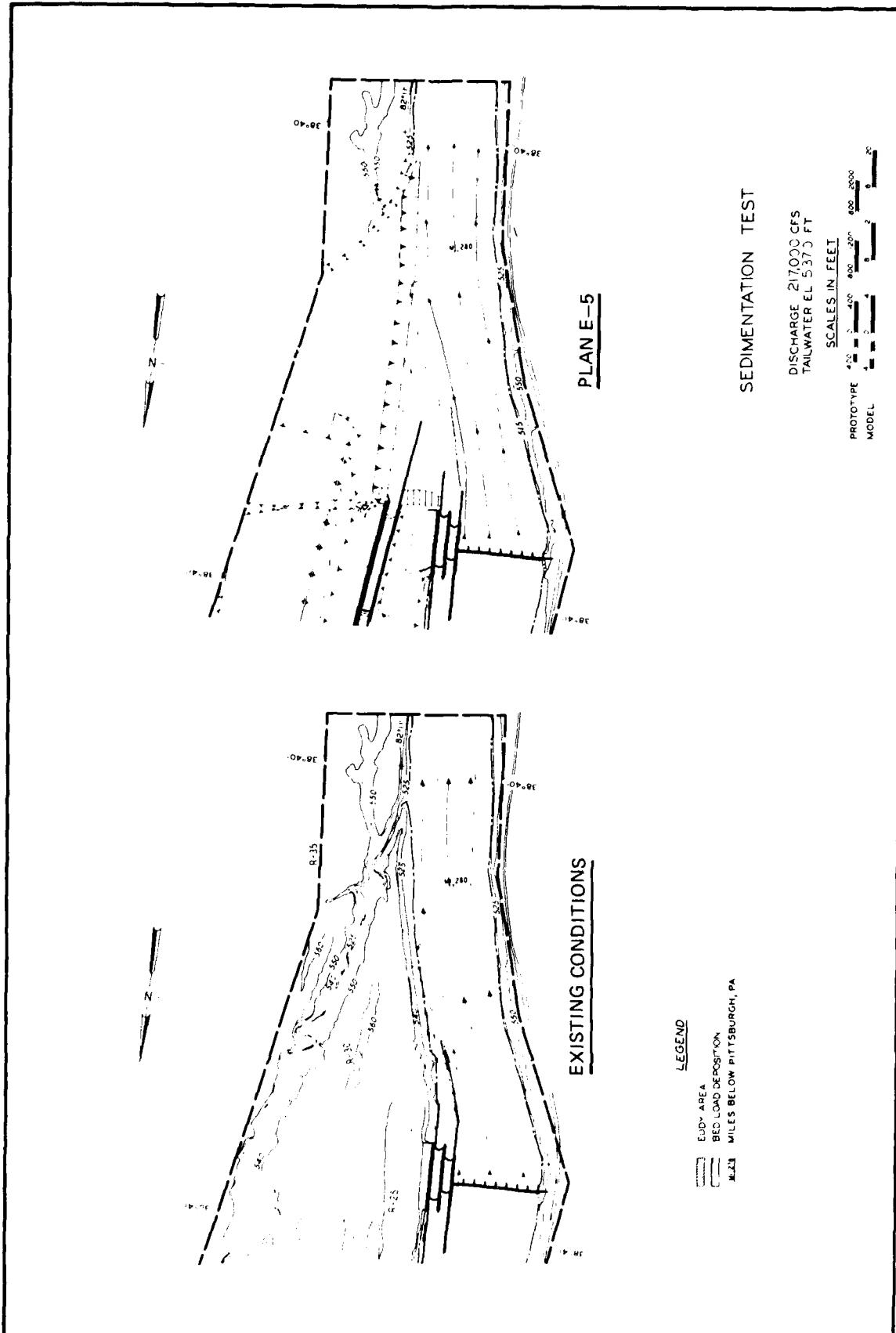
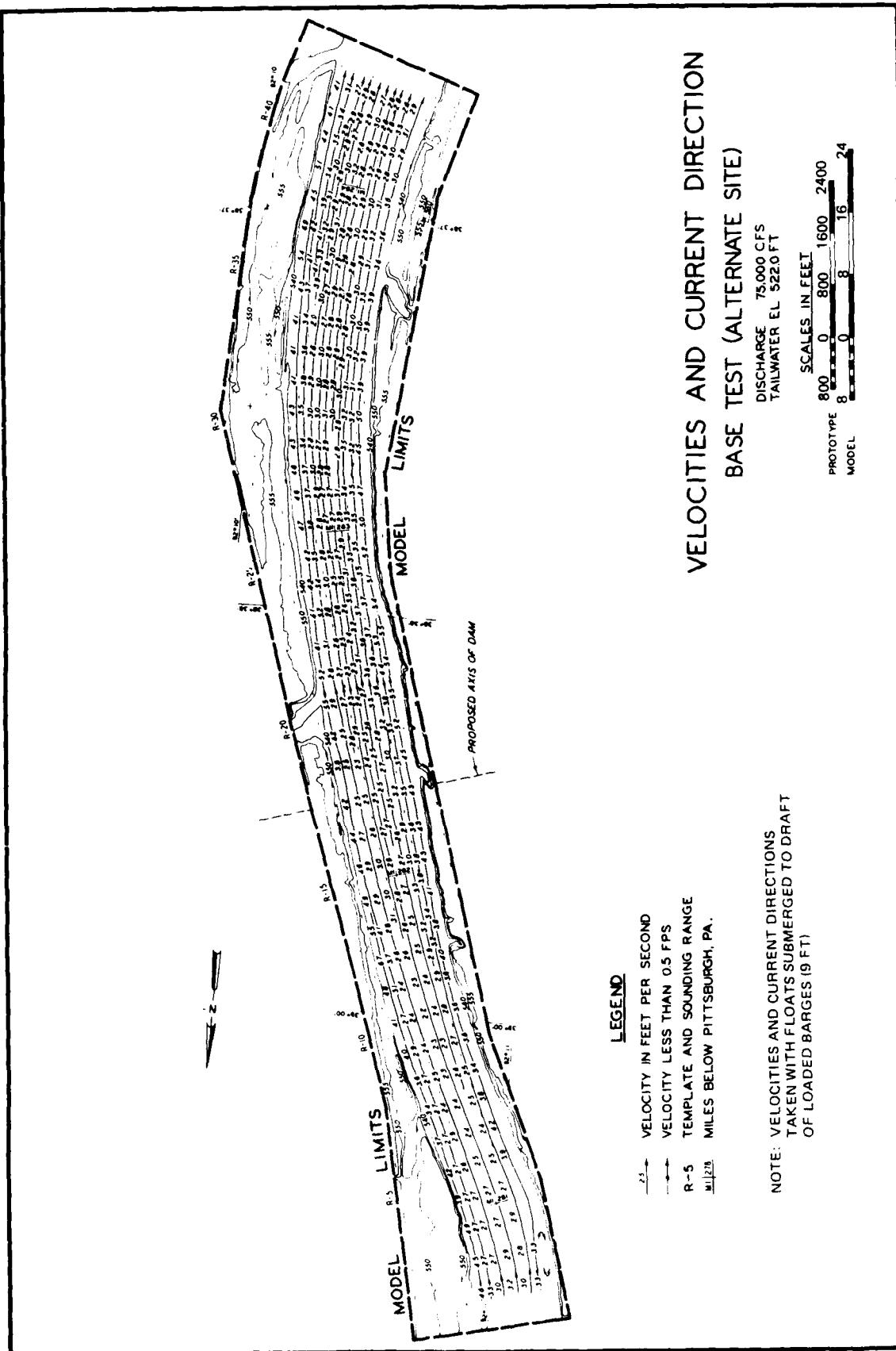


PLATE 52







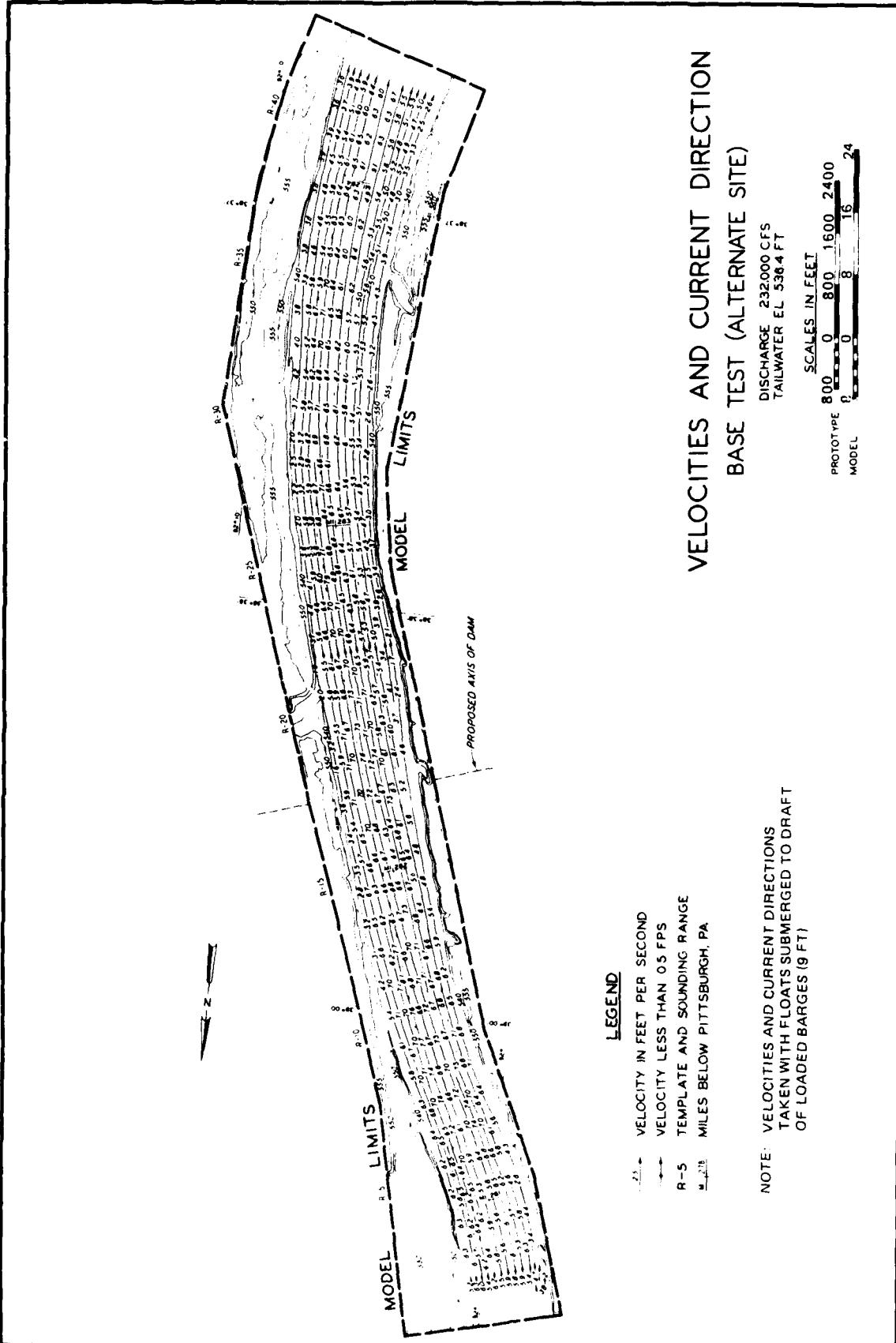
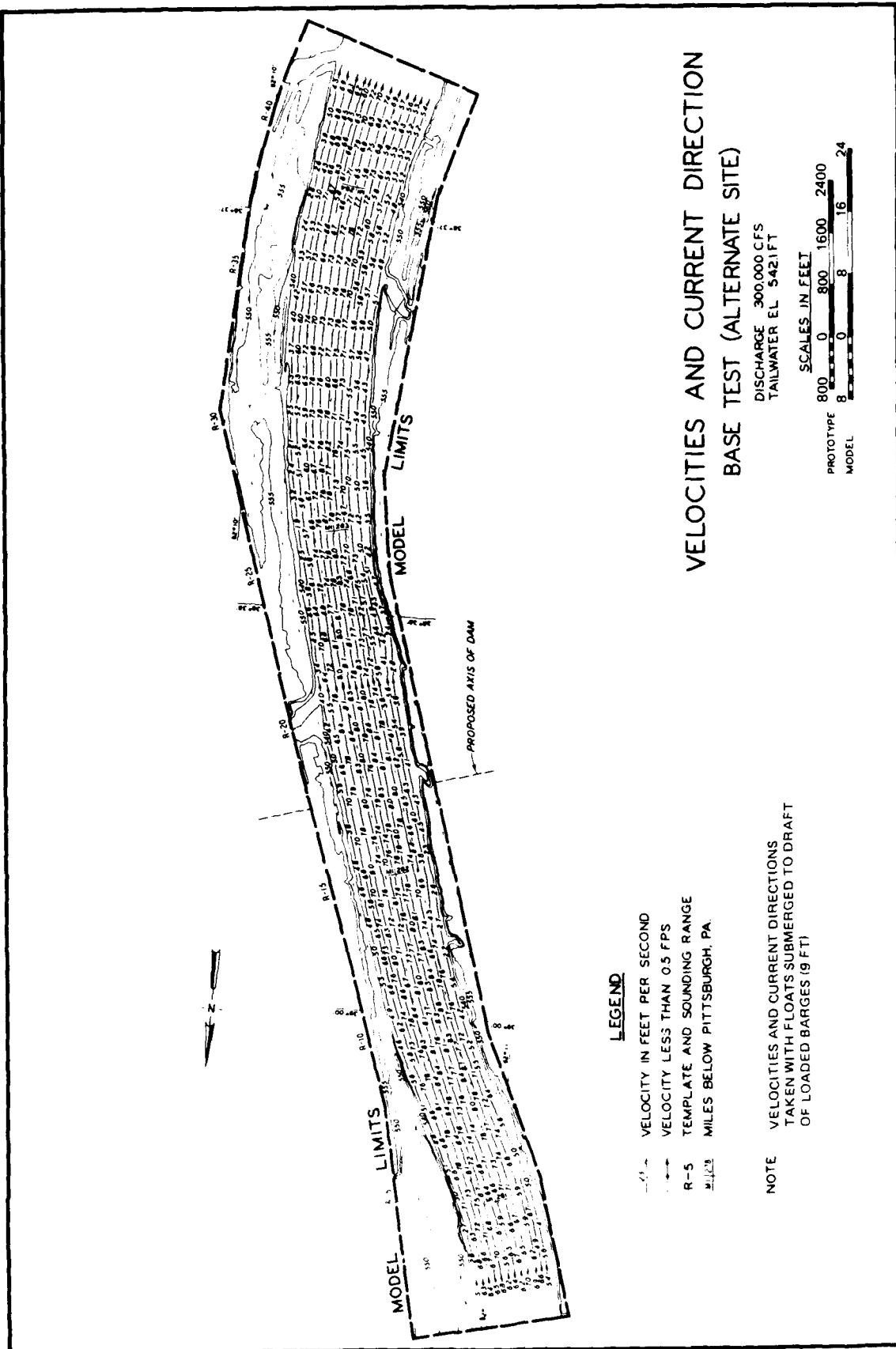
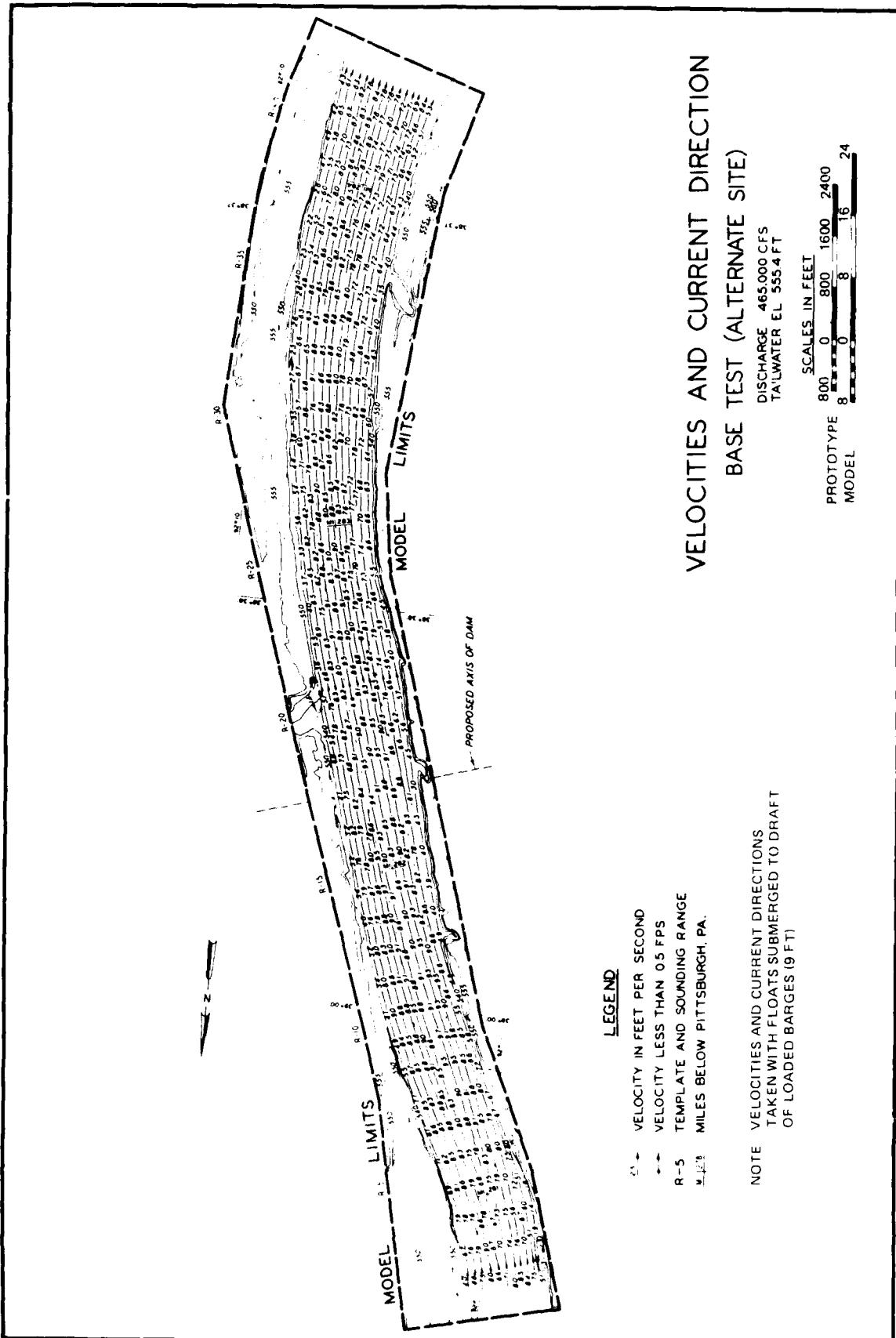
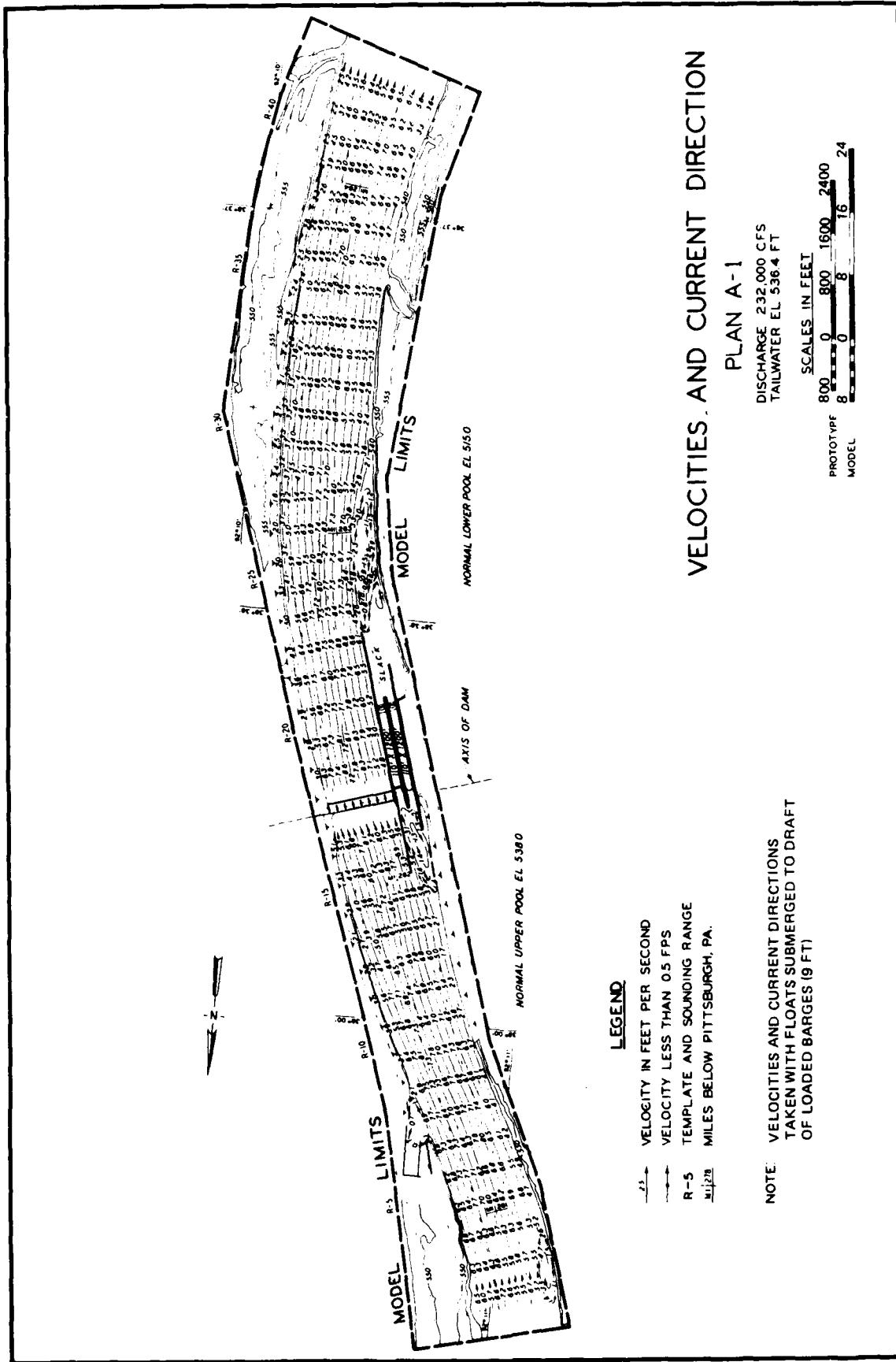
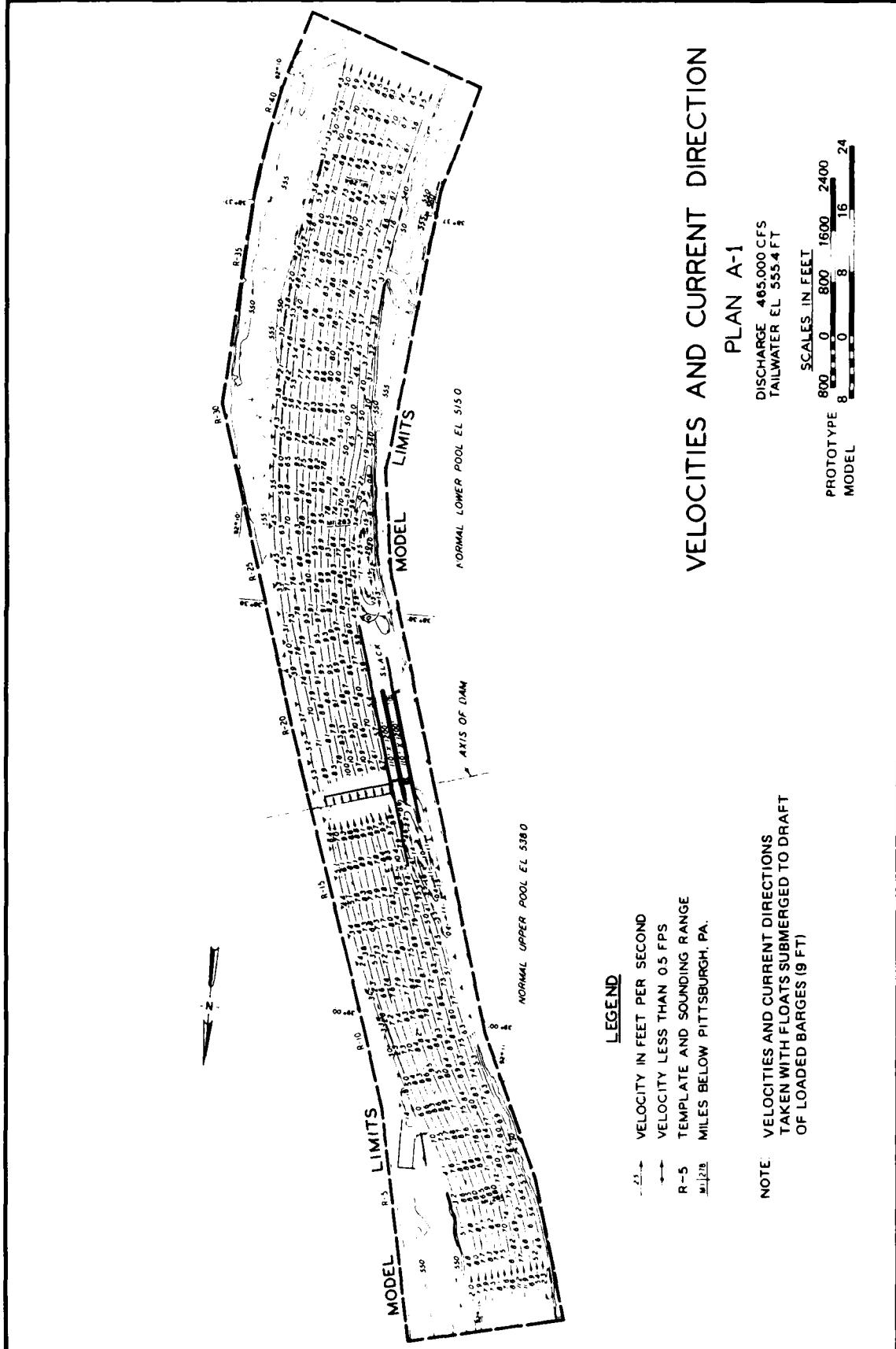


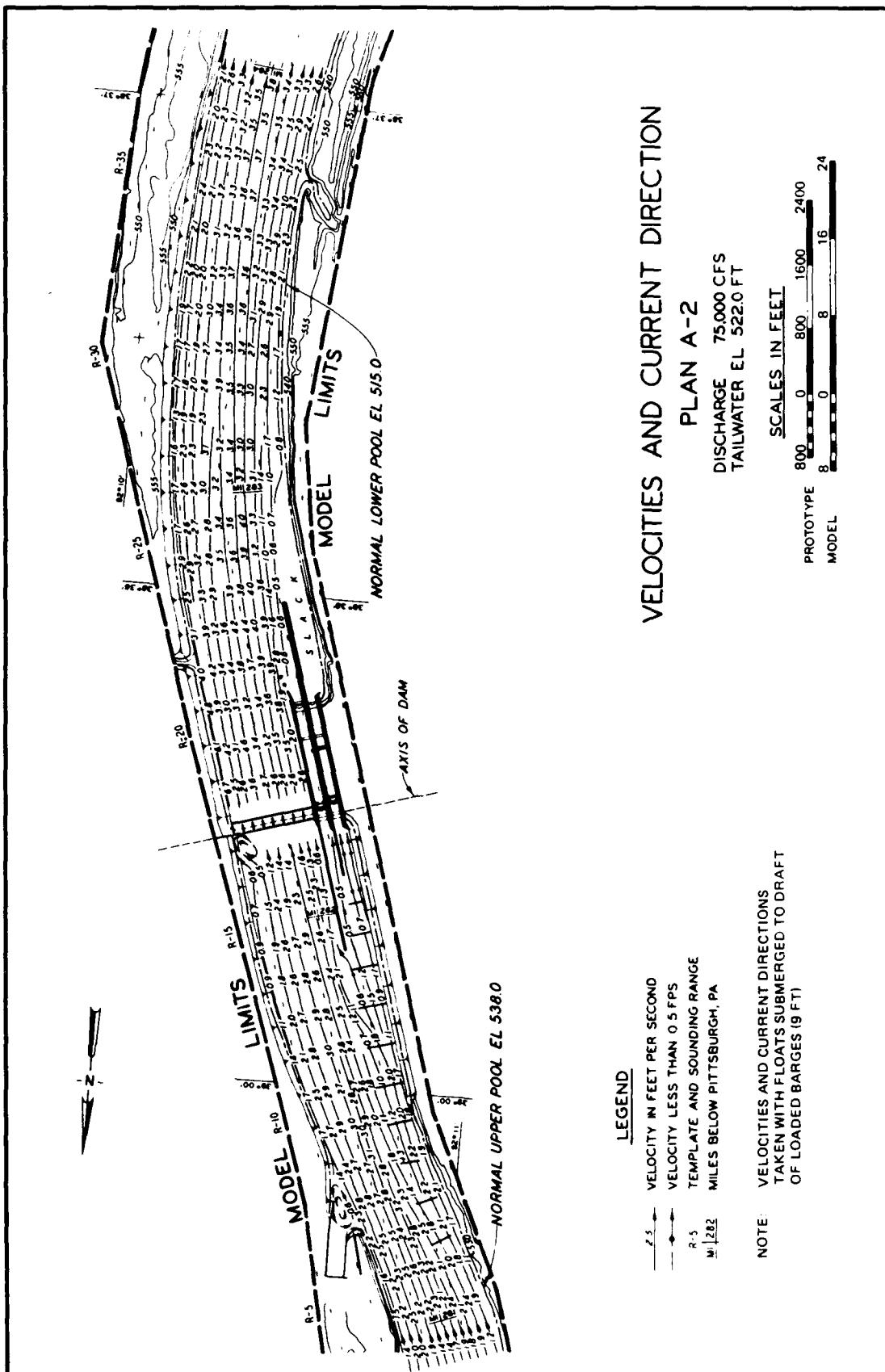
PLATE 56











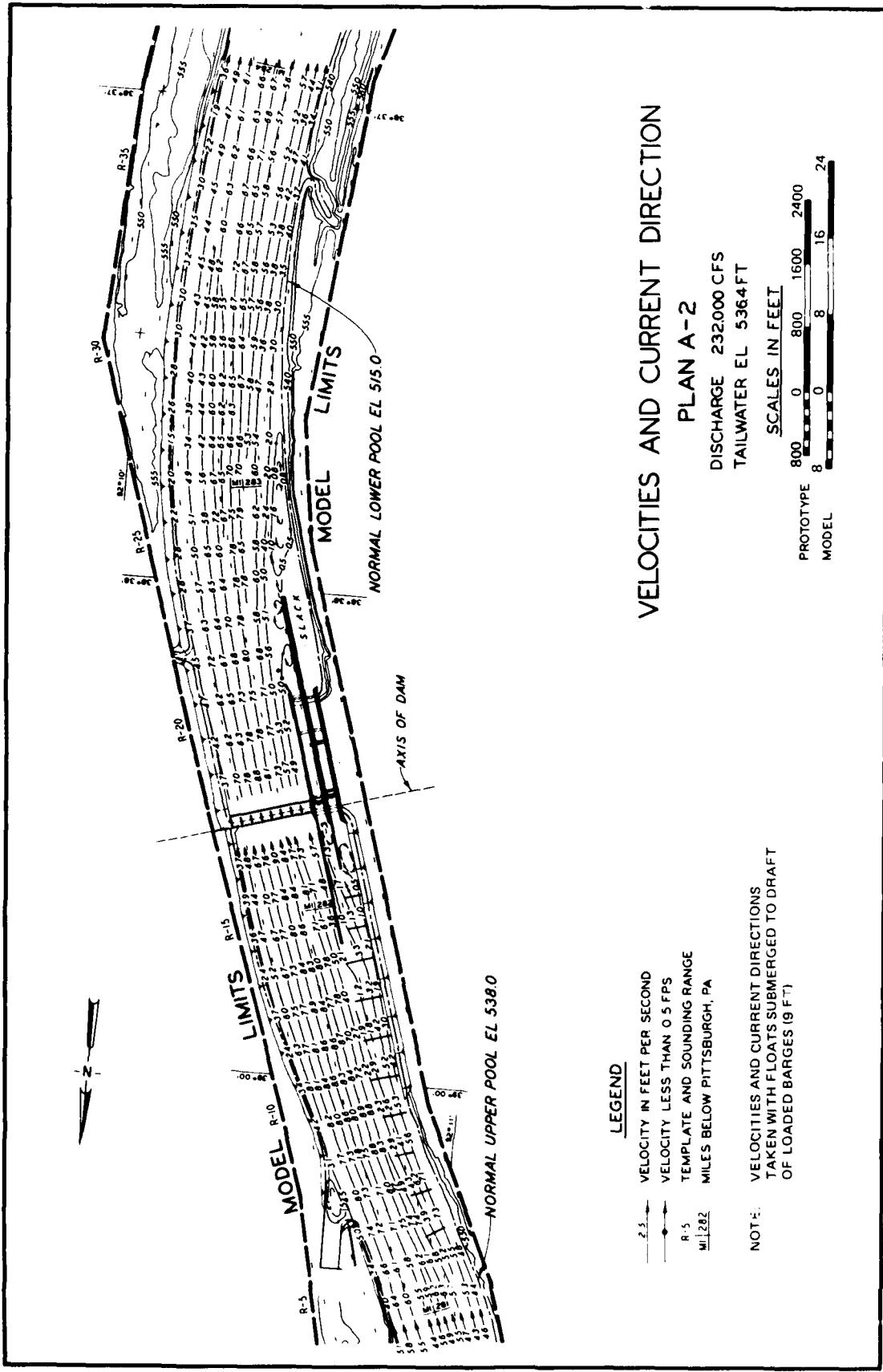
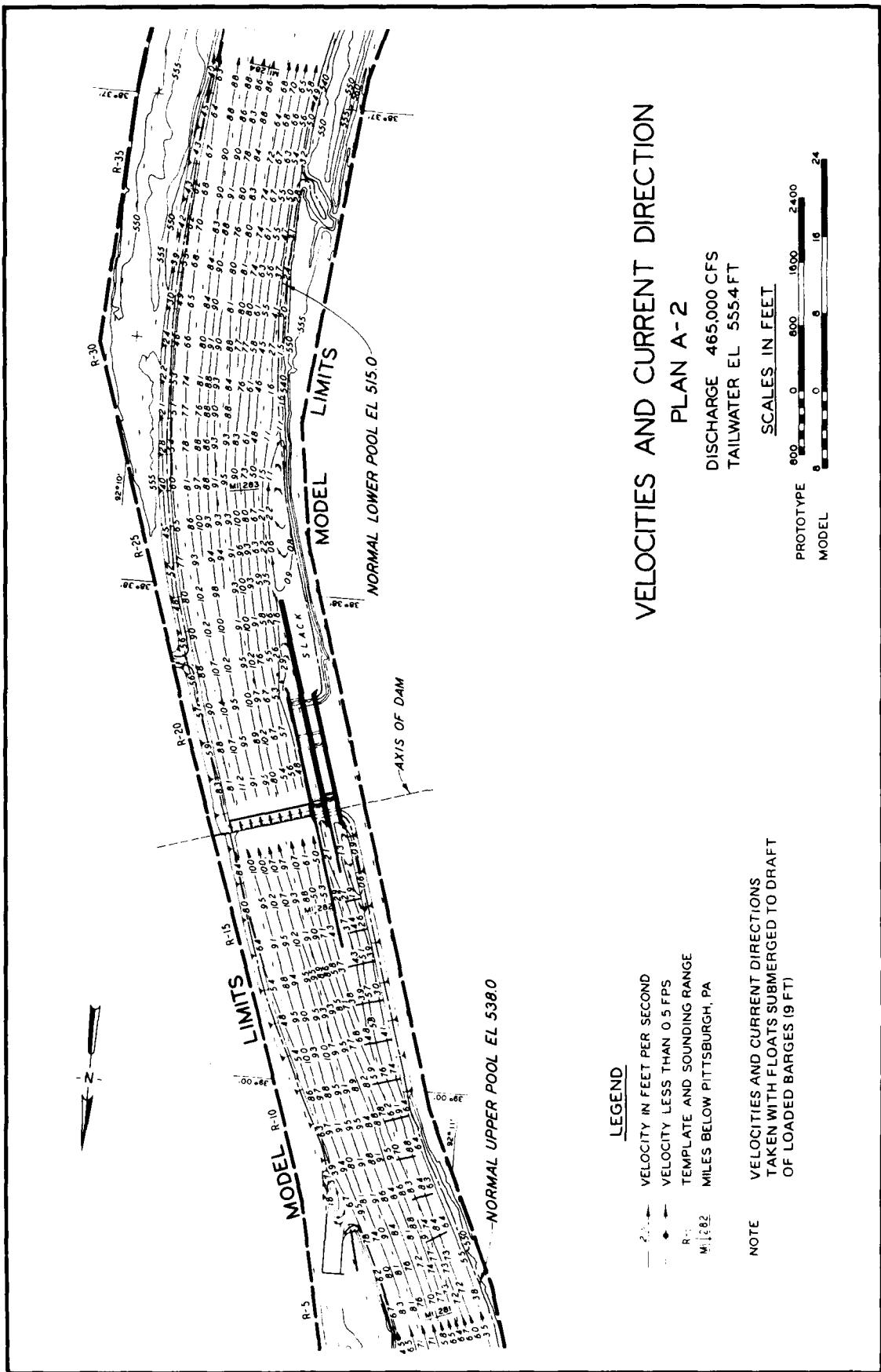


PLATE 62



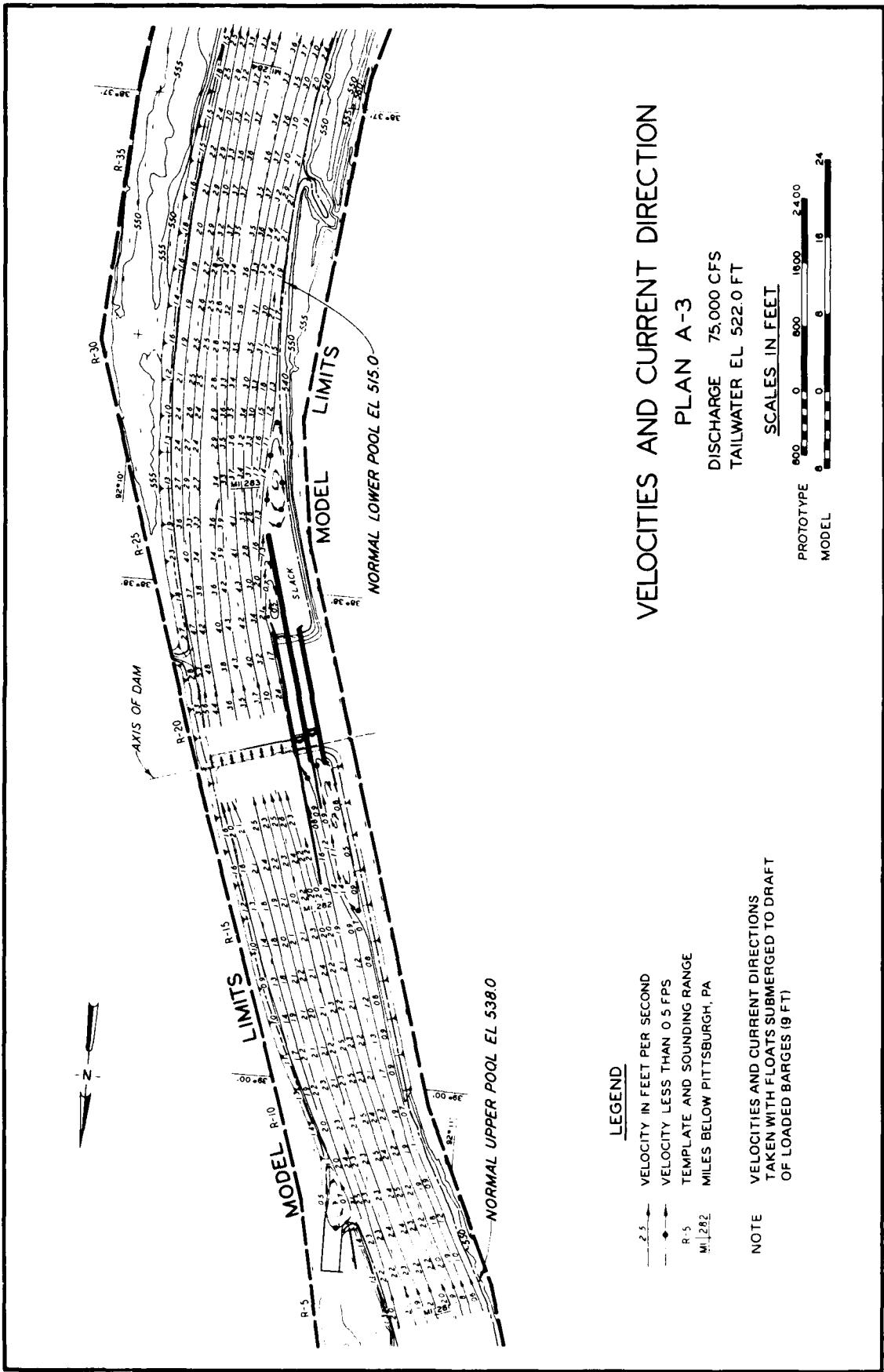


PLATE 64

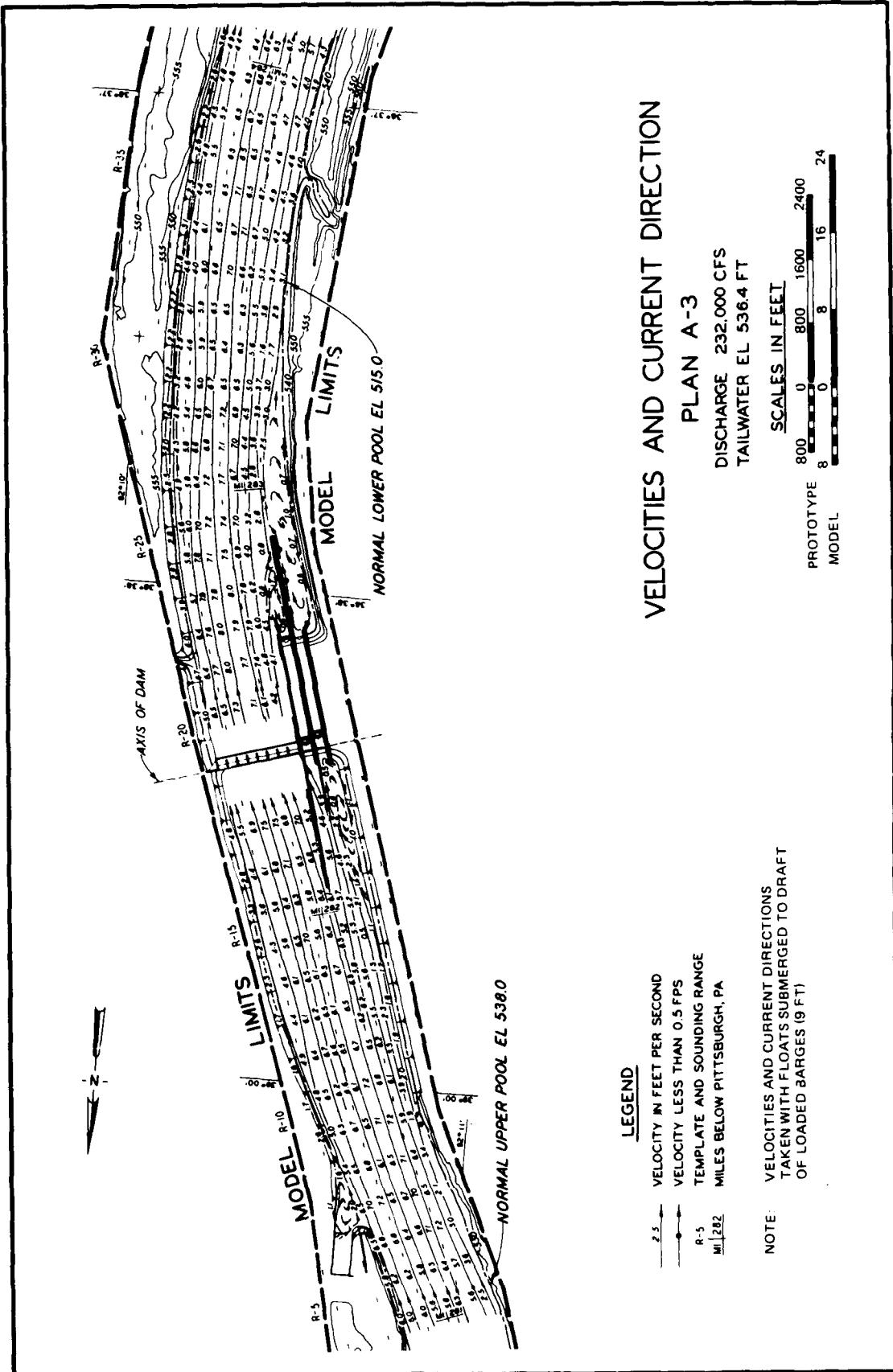


PLATE 65

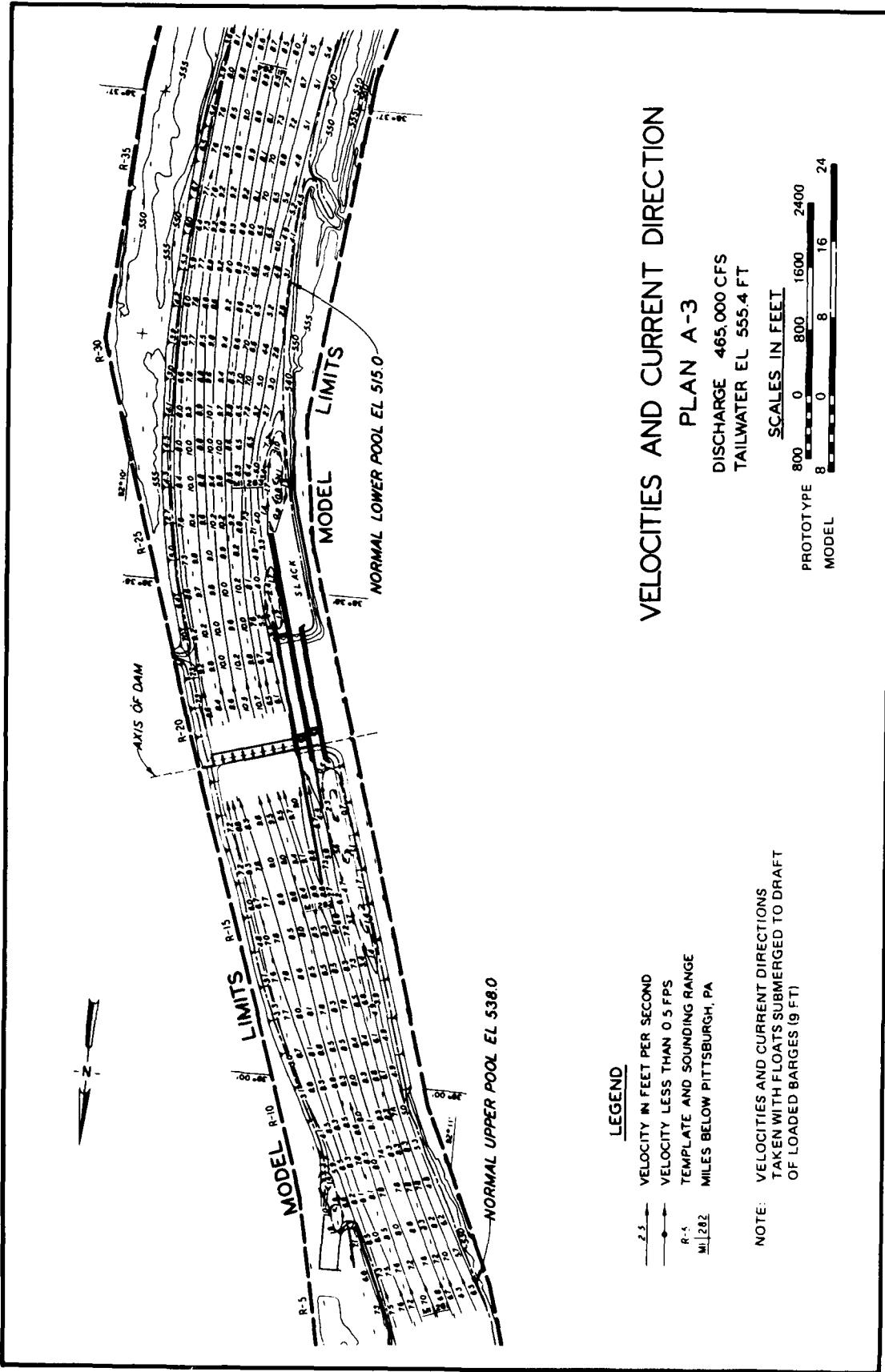


PLATE 66

